AD-A080 469 UNITED TECHNOLOGIES CORP WINDSOR LOCKS CONN HAMILTON --ETC F/G 8/2
A COLOR RASTER SCANNING SYSTEM FOR DIGITIZING CARTOGRAPHIC DATA--ETC(U)
NOV 79 D MODEEN, S NIEMCZYK, F SUNDERMEYER F30602-76-C-0205
UNCLASSIFIED HSER-7673 RADC-TR-79-286 NL

1 of 2
AD
A080469

LEVEL II

12

RADC-TR-79-286
Final Technical Report
November 1979

ADA080469

A COLOR RASTER SCANNING SYSTEM FOR DIGITIZING CARTOGRAPHIC DATA

Hamilton Standard Division of United Technologies Corporation

Douglas Modeen
Stephen Niemczyk
Frank Sundermeyer
Richard Hubbard

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

80 2 7 047

This report has been reviewed by the RADC Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be releasable to the general public, including foreign nations.

RADC-TR-79-286 has been reviewed and is approved for publication.

APPROVED: Francis T. Kulon

FRANCIS T. KULON
Project Engineer

APPROVED: Howard Davis

HOWARD DAVIS
Technical Director
Intelligence and Reconnaissance Division

FOR THE COMMANDER: John P. Huss

JOHN P. HUSS
Acting Chief, Plans Office

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(19) REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (18) RADC-TR-79-286	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) (6) A COLOR RASTER SCANNING SYSTEM FOR DIGITIZING CARTOGRAPHIC DATA	5. TYPE OF REPORT & PERIOD COVERED (9) Final Technical Rep[redacted]t, May [redacted]76—June [redacted]79
	6. PERFORMING ORG. REPORT NUMBER (14) HSER-7673
7. AUTHOR(s) (10) Douglas/Modeen, Stephen/Niemczyk, Frank/Sundermeyer, Richard Hubbard	8. CONTRACT OR GRANT NUMBER(s) (15) F30602-76-C-0205
9. PERFORMING ORGANIZATION NAME AND ADDRESS Hamilton Standard Division of United Technologies Corporation Windsor Locks CT 06096	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 64701B (16) 43030325 (17) 03
11. CONTROLLING OFFICE NAME AND ADDRESS Rome Air Development Center (IRRP) Griffiss AFB NY 13441	12. REPORT DATE (11) Nov[redacted]79
	13. NUMBER OF PAGES 106
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Same (12) 114	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Same

18. SUPPLEMENTARY NOTES

RADC Project Engineer: Frank T. Kulon (IRRP)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Raster Scanning	Raster File Merge	~~Graphic Noise Filtering~~
Automated Hydrography	Raster File Update	Raster Data Compression
Cartography	Color Separations	Image Enhancement
Screen Detection	Lithographic Reproduction	Raster Image Scaling
Process Color Detection	Color Detection	Raster Image Distortion Removal
		Raster Image Skew Removed

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The final technical report on the Color Raster Scanner system described the principal system requirements, and the technical considerations leading to the definition of the design approaches employed. The resulting system is composed of major functional elements in hardware, in software, and in the operator support interfaces. This latter area is of high importance in applying the Scanner capabilities to obtain satisfactory results in the use of the scanned cartographic data. → next page

(Cont'd on reverse)

DD FORM 1 JAN 73 1473

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

161 400

The report contains a functional description of the Color Raster Scanner system in all its subdivisions, and includes results of test and evaluation as obtained.

The major units of the system are the Drum Scanner Unit, the Data Preprocessor, the Control Microprocessor with its I/O control and display hardware, the Model 8/32 Processor System, and the Applications Software which supports, controls, and integrates system operations.

The Drum Scanner Unit includes the mechanical structure which makes possible the basic positional accuracy ($\pm$ 0.050mm) and repeatibility ($\pm$ 0.025mm) realized from its mechanical precision, and the accuracy of the positioned encoding employed. The Drum Scanner Unit includes the Scan Head which produces color measurements of cartographic inputs enabling color and data form information.

The hardware and software functional descriptions follow the flow of data from photodetection to its recording in digital form on magnetic tape. The software is described in its diverse applications of operator support, on-line processing of data as scanned and off-line processing of output scanned data to requirements which entail more extensive file manipulation.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

EVALUATION

The equipment described in this report was developed for implementation by the Defense Mapping Agency (DMA). Previous methods employed by DMA in the preparation of data for chart production included both strictly manual and manual digitizing techniques. Both of these methods are labor intensive and time consuming. The color scanner will enable the DMA to automatically extract the information contained on hard copy analog sources and to output that data in digital form.

The color scanner was developed in direct support of RADC TPO R2D "Precision Targeting and Charting." With this increased capability, DMA will be able to respond more rapidly and accurately to requests for charts and cartographic related products.

FRANCIS T. KULON
Project Engineer

SECTION I

INTRODUCTION

This is the final Technical Report covering the work accomplished in the design, development, and installation of the Color Raster Scanner under Contract Number F30602-76-C-0205 with Rome Air Development Center, Griffiss Air Force Base, New York. The Scanner has been installed in the Automated Hydrography Branch of the Defense Mapping Agency Hydrographic/Topographic Center, Washington, D.C.

The design approach and performance characteristics provided in the hardware and the software of the Color Raster Scanner were developed to fulfill the specific requirements of the Statement of Work, PR No. I-5-4709, dated 1975 June 5, and Amendments No. 1 and 2. The Statement of Work defines in detail the Scanner functional characteristics required to satisfy the needs of DMAHTC in color raster scanning of lithographic charts of foreign origin. Although the Scanner was designed and developed to meet the requirements of the specified application, it is capable of use in other color raster scanning requirements with different input materials, and different data extraction objectives. This includes various forms of cartographic data on opaque bases, and on transparencies in black-and-white, or color.

The Scanner operational requirements may be grouped into the mechanical, optical, electrical, and software technologies necessary to meet the requirements of the Scanner application. In the following paragraphs, the operational requirements of most significance, and of most interest, are summarized and briefly discussed in leading up to the description of the design and development accomplishments in all technical areas of the Scanner.

The principal requirements of the Statement of Work which impact the mechanical subsystem are the accuracy, repeatability, physical size, and running speed.

The mechanical subsystem is defined to be the structure to which input chart materials are attached, together with the mechanism by which the chart is optically scanned in a raster format coincident with the orthogonal coordinate system of the machine. The subsystem is referred to as the Drum Scanner Unit.

In order to realize the required repeatability of ± 0.025mm, and an accuracy of ± 0.050mm between any two points on the drum surface, careful attention must be given to mechanical tolerance control,

deflections, differential expansion rates, bearing play, and balancing of rotating parts. Given the mechanical precision of the unit necessary to achieve the required accuracy and repeatability, the implementation of the measurement of coordinate position is important to the realization of that performance, particularly with respect to the high resolution together with the scanning speed required by the specified scan time for the largest size chart to be employed.

The requirements of the Statement of Work of most technical significance to the optical functions are:

1.) the smallest chart area source of input signal, corresponding to 0.025 mm diameter. This source size significantly limits the magnitude of the input radiant power, and impacts the selection of the source of chart illumination and the choice of a photodetector.

2.) the recognition of the type of data - even tone color, screen, or process color - present on the lithographic source, and the mix of types which may be present on a given chart. Because the process color method creates a color from the combination of dots of a few primary colors, differing in dot size and screen angle, the resulting color visually sensed is the sum of the component dots. To obtain the same color recognition instrumentally, the chart area from which the input signal is produced must be large enough to yield an equally distinctive result as that of the visual response. Similarly, with screens the density is established by the dot size; i.e., the area covered by ink per unit of area on the chart. The recognition of process colors and screens impacts the optical system by the requirement for the relatively large area signal measurement, at the same time requiring the resolution-scale input measurement for even tone (solid) color graphic data which exists with screen or process color presentations.

3.) the detection and identification of a set of five colors plus black and the base (substrate) on a single scan. This requirement is significant because of the low contrast between some inks used, and between inks and the base, on lithographic sources representative of those intended to be employed on the Scanner.

The electrical hardware implements the physical transfer of data from the photodetectors to an input of the Processor system for recording in a mass storage medium. The electrical hardware also provides for control, monitoring, display, and discrete switching functions. The extent to which these functions are carried out in hardware alone, or by a combination of hardware and software was an important consideration of system design.

The critical requirements on the electrical hardware are those which are performed on-line,i.e., during active scanning operations. Among the operational processing required on the scanned data, some functions present an alternative of being performed in hardware or in software. Since the data spends little time in the hardware, or in the working memory of the Processor, on-line implementation in either case is limited to those functions which can be carried out in the very short time afforded by the data rate. The operations which should be assigned to the hardware are those which minimize the amount of data per unit time which is generated and sent to the Processor. These functions consist of color and screen (process color) identification, data compression and word formation, and the filtering of elements of color or void which are present for a limited run length.

The software requirements on the Color Raster Scanner include the explicit support functions specified by the Statement of Work: Update of a raster scan data file by merging a scanned amendment; change of scale of a raster date file; removal of distortion from a raster file introduced by the chart base; and separation of a scanned data file by color in a format required to drive the DMA Raster Finishing Plotter. These software functions may be employed on the scanned data file following completion of the active scanning of the chart; consider-ation of the practicalities in providing these functions in parallel with the data acquisition was a system design consideration. On-line Processor software requirements consist of the processes involved in reading the scanned data input by the hardware, and organizing, for-matting, and writing it out to mass storage; in addition, the Processor software must provide for the on-line display of scanned data on a graphic display unit.

Implicit in the identification of color and type data on charts is the need to enhance the interpretation of data made by the hard-ware, by correcting anomalies in data identification resulting from any mixes of chart data in the element of area producing the detected signal. This occurrence imposes a requirement on the software for editing of the scanned data to make the necessary corrections.

Other requirements of the Scanner which involve hardware and software, or both, and represent operational functions studied from the system design point of view to determine their form of implementation, consist of such items as:

1.) the correction of the coordinate distance in the circumferential direction on the basis of different chart thicknesses,

2.) the selection (or deletion) of one or more colors from a chart in the generation of an output record file,

3.) the capability to accept the data within selected areas of the chart, or to delete the data contained in selected area of the chart. Up to 10 areas defined by their corner positions in Scanner coordinates must be accommodated.

4.) calibration of the chart for system identification of chart colors and data types.

Beyond the requirements which are specifically identified by the Statement of Work there exist considerations of a systems nature which include the communications between the different functional units for monitoring, checking, control, and command purposes in keeping all elements of the system in connect operational synchronism.

SECTION II

COLOR RASTER SCANNER SYSTEM DESIGN DESCRIPTION

The functional design definition of the Color Raster Scanner system did not fundamentally change from that of the proposal, throughout design and development, to the delivered configuration. The system is shown in basic form in Figure 1. The calibration functions were developed as an operating mode of the Data Processor hardware, rather than as the independent hardware assembly initially described. The system control functions of the Scanner were designed and implemented in the Control Microprocessor (INTEL 8080) rather than in fixed logic. This approach provided the advantage of flexibility in the design and development phase, it required a minimum of hardware for implementation compared to discrete I.C. logic packages, and it permits change and/or growth with least impact on the hardware.

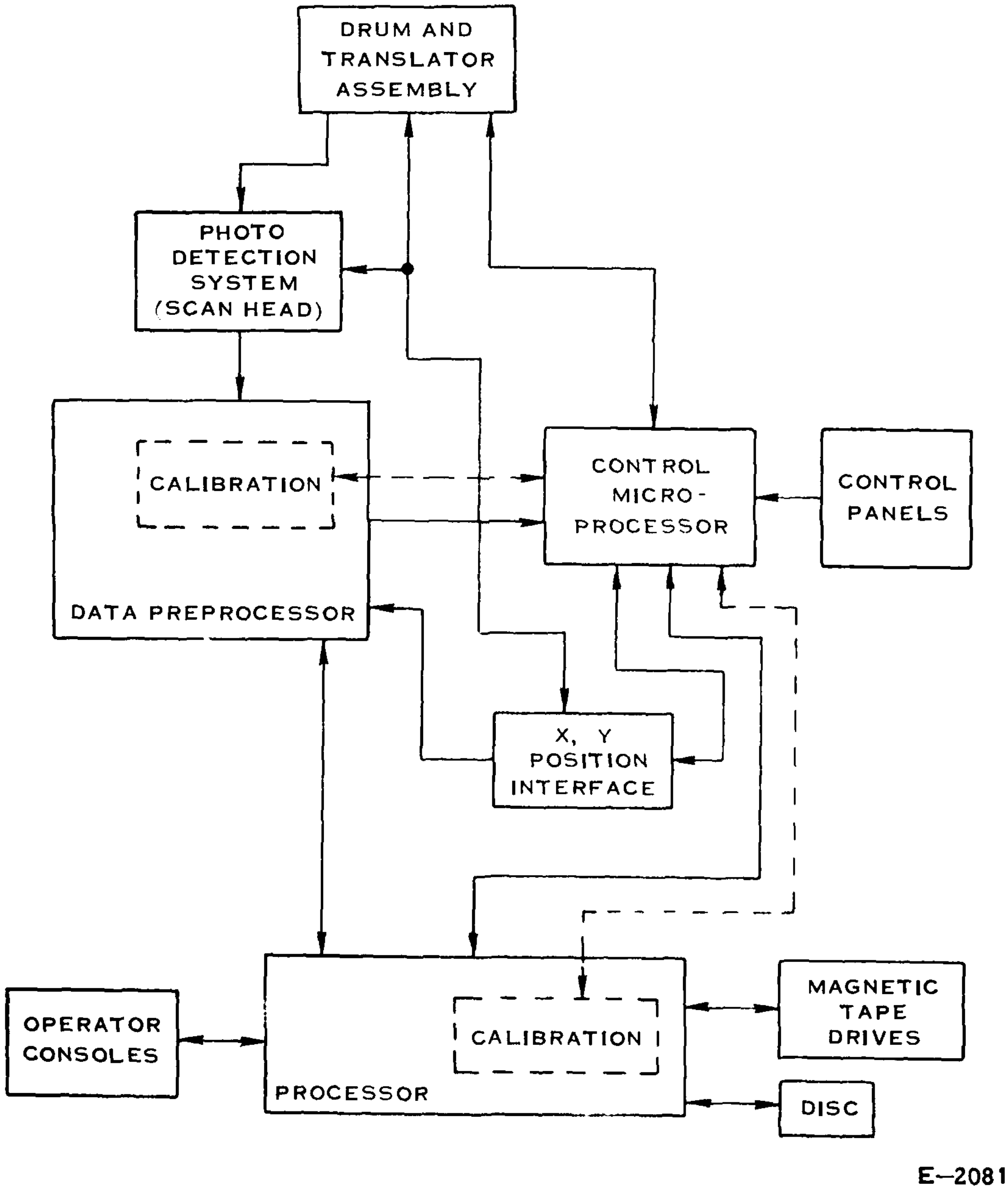


FIGURE 1 COLOR RASTER SCANNER FUNCTIONAL BLOCK DIAGRAM

A. System Description

The Color Raster Scanner system is described from the point of view of its principal functional units, each having recognized interfaces, and which together implement the total Scanner capabilities. Each principal unit of the Scanner, shown in Figures 2 and 3, is briefly described in the following paragraphs.

Mechanical System

The mechanical system is the fundamental element of the Color Raster Scanner. Its design makes possible the basic precision required in the functional performance of the machine. The mechanical system consists of a horizontal Drum assembly, frame assembly, and the service functions of the vacuum system and compartment ventilation. Position on the Drum surface is provided by shaft encoder in the x-coordinate direction and by controlled ball-screw advance of the translator carriage in the y-coordinate direction. A shaft encoder attached to the ball-screw provides a feedback signal which is used to monitor ball-screw motion.

The Drum drive utilizes a DC servo motor with tachometer feedback. This drive approach provides a one-minute Drum start and stop time and holds the Drum speed constant at 300 RPM for the scanning operation.

The carriage drive is provided by a D.C. stepper motor with 400 steps per revolution; each step produces 0.0125mm linear motion of the carriage in the y-coordinate direction.

Photodetection System

The photodetection system is contained within the Scan Head mounted on the translator carriage. Its basic function is to convert the light flux reflected from the scanned chart surface into electrical signals by which the chart colors, screens, and process color data may be identified. Supplementary to this basic function is the visible light source which illuminates the scanned chart for the spectral measurements. Optics form an image of the collected light, which is sampled

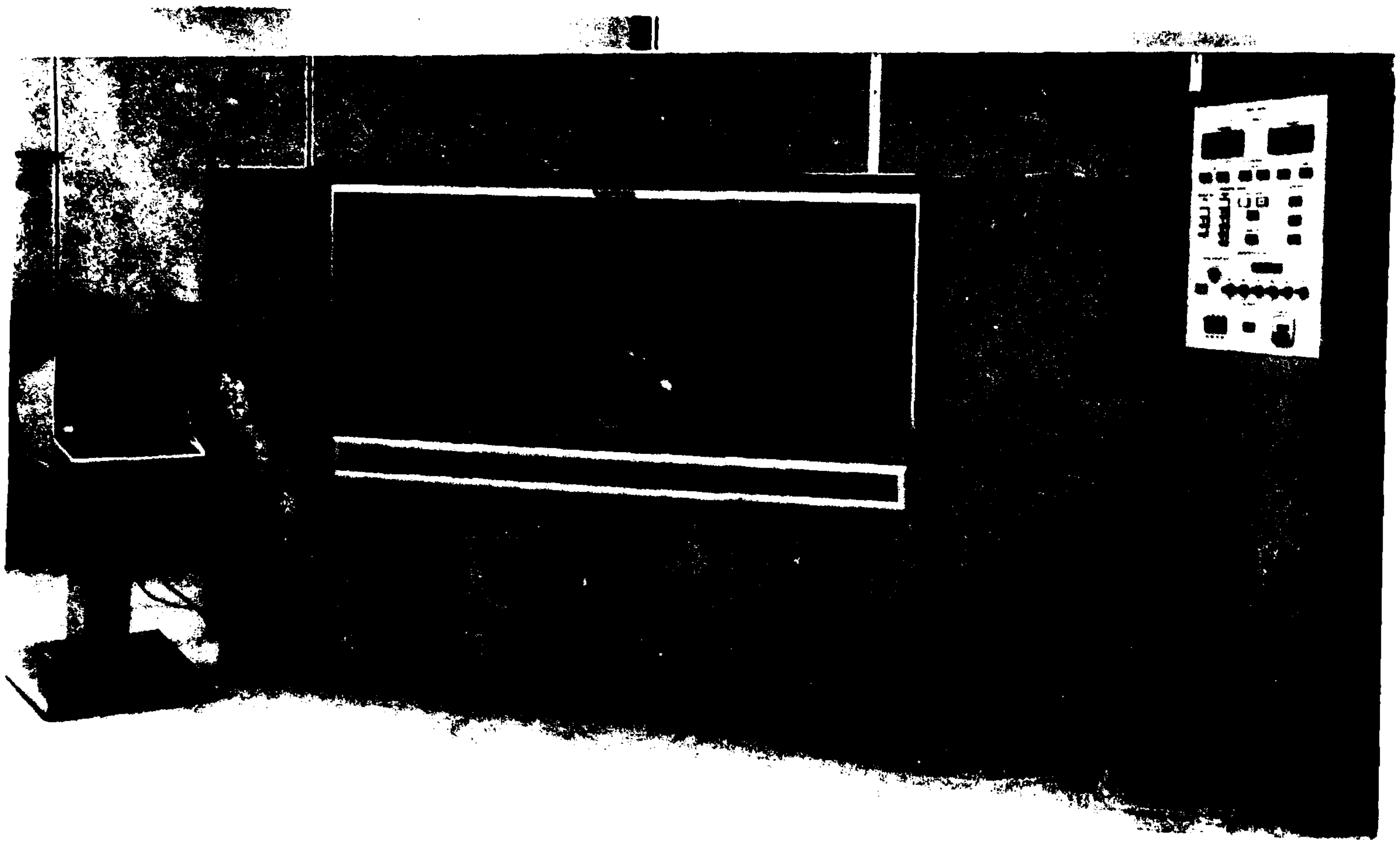


FIGURE 2   DRUM SCANNER UNIT AND PROCESSING CONSOLE

FIGURE 3 MODEL 8/32 PROCESSOR SYSTEM

by an aperture of equivalent resolution dimensions, and divided into three spectral bands in the visible region for measurement by photomultiplier tubes. Additional optics form images which are sampled by apertures of larger than resolution size dimensions. These apertures are sized to integrate screen or process color half-tones. Signal conditioning electronics are provided to condition the photomultiplier signals for transmission to the Data Preprocessor in analog form.

Operator viewing provisions are built into the Scan Head to check focus of the optical system, to provide a means of detail examination of the chart surface, and to precisely position the Scan Head optics over any specific point on the chart.

Data Preprocessor

The basic function of the Data Preprocessor is to detect five colors plus black and white, recognize the presence of screen or process color, and then compact this color/screen/process color information into 16-bit run-length format Transition Data Words. The run-length format data words are transferred to the 8/32 Processor memory via its DMA channel where they are temporarily held in a scan line data buffer, processed on-line and then transferred to magnetic tape.

The Data Preprocessor operates in two basic modes: Calibrate and Scan. In the Calibrate Mode "raw" color and lightness measurements are transferred from the Data Preprocessor to the 8/32 CPU where color discrimination parameter limits are calculated. As the final step in the Calibrate process these limits are transferred from the Model 8/32 to the Control Microprocessor and, thence, to the Data Preprocessor where they are stored and used to discriminate colors and screens in the Scan Mode.

The color discrimination technique used in the Color Raster Scanner is one which obtains the ratios of each of three spectral band signals to the total of the three signals measured. A lightness signal formed by summing the three spectral signals is also utilized. Performance of simultaneous logical comparisons of ratio and lightness values against the stored cali-

brated values result in color, white or black identification; for screen and process color lighography, the color samples use an aperture size sufficient to integrate the halftones and produce spectral measurements representative of the color portrayed.

Control Microprocessor

The Control Microprocessor consolidates the control of operations in the mechanical system including Drum and translator carriage motion. The Control Microprocessor also establishes and displays operating and functional parameter settings via the system control panels. Finally, the Control Microprocessor interfaces with the 8/32 Processor and the Data Preprocessor in calibration, initialization, testing and the intercommunication of control and status information.

X, Y Position Interfaces

Position along the Drum circumferential (X) direction is maintained by an 80000 pulse-per-revolution shaft encoder whose output pulses are counted and read by the Control Microprocessor for position determination and display. A once-per-revolution encoder reset (X_o) pulse establishes an absolute X-origin.

Position along the Drum axial direction is maintained by the Control Microprocessor which, for all Scanner manual and automatic modes of operation, supplies pulses to the stepper motor which rotates the ball-screw and advances the Translator. The Control Microprocessor keeps a count of the total (counterclockwise minus clockwise) pulses supplied to the stepper motor. This count is used for Y position determination and display. A Y = 0 position sensor establishes the Y absolute origin. Pulses output from an encoder attached to the ball-screw are counted and read by the Control Microprocessor to verify ball-screw advance.

8/32 Processor

The 8/32 Processor configuration shown in Figure 4 is provided for the Color Raster Scanner. The 8/32 Processor collects the scan data and transfers the data to magnetic tape in Scan Record Tape Format. A subsequent

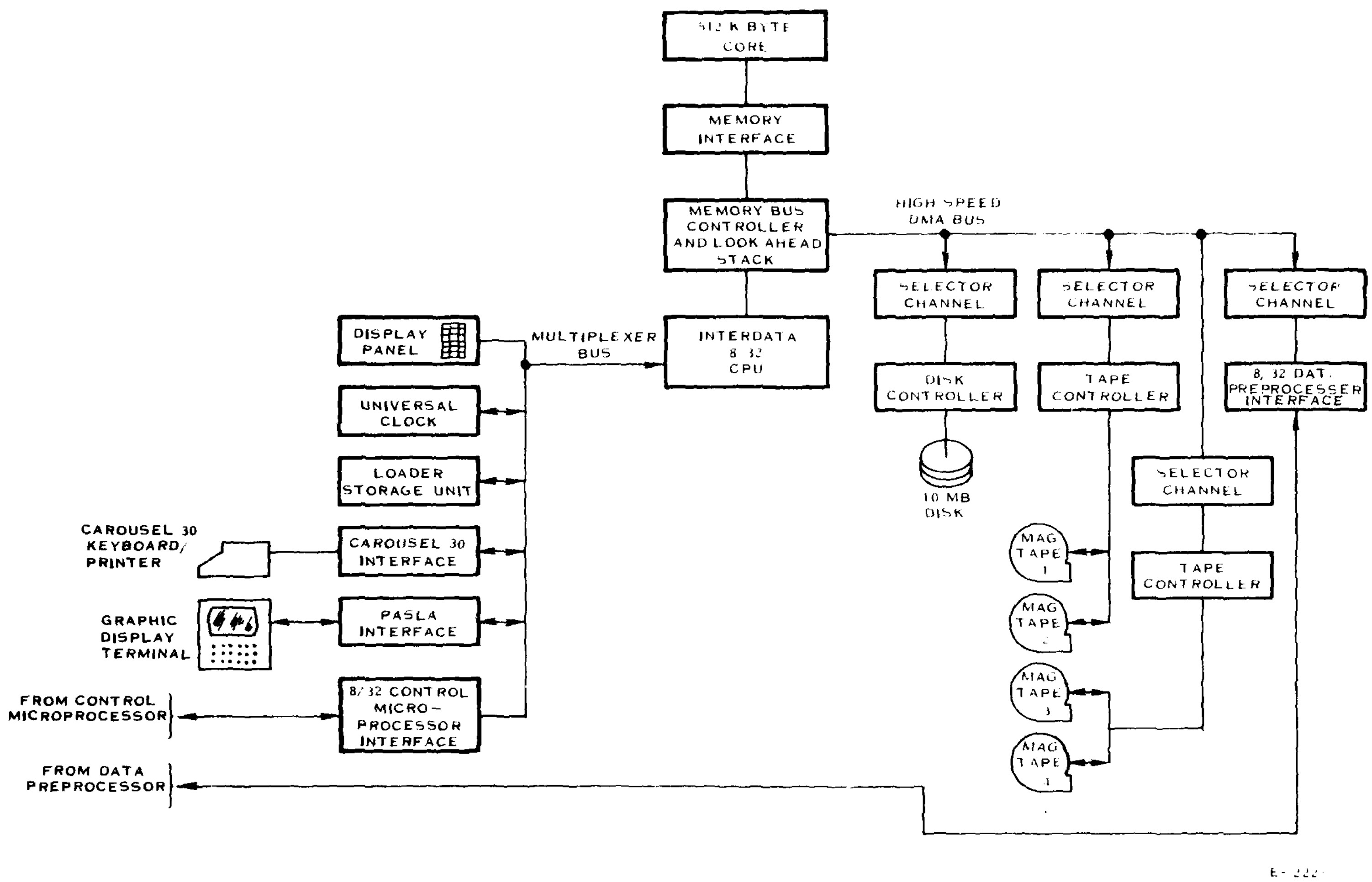


FIGURE 4 COLOR RASTER SCANNER CPU BLOCK DIAGRAM

processing operation produces an Edited Scan Record Tape in which the problems associated with voids, short color spans, screen boundaries and overprints are minimized. The support functions of distortion removal, change of scale, merge and Raster Finishing Plotter color separation tapes are also performed as required. The 8/32 Processor configuration consists of the computer main frame and peripheral devices. The major components are listed below:

Main Frame - Interdata Model 8/32 processor with 512K byte core memory, universal clock and loader storage unit.

Peripheral Devices - Carousel 30 Keyboard/Printer - The Interdata Carousel 30 Keyboard/Printer terminal provides a 30 CPS printer and a 132 character print line. It is used as the main system console and also to produce output reports to document the Scanner operations.

Tektronix 4006-1 Graphic Display Terminal (GDT) - The GDT displays a sequence of "menus" which guide the operator through the Scanner operations and prompts the operator's actions. The GDT also produces a display of the scan in progress.

Disc - A Pertec 10 MB disc (5 MB fixed, 5 MB removeable) is utilized for data and application program storage.

Magnetic Tape - Four Kennedy Model 9100 tape units are configured in the system. Two tape units accept the Scanner output data as it is produced. The two additional tape units are employed in supporting the post-processing function requirements. Two Tape Controllers interface the tape units with the 8/32 Processor and provide 800/1600 BPI selectable encoding at 75 IPS.

8/32 - Control Microprocessor Interface - An Interdata Universal Logic Interface board in adapted to handle the 16-bit parallel half duplex protocol which is employed for 8/32 Processor-Control Microprocessor intercommunications.

8/32 - Data Preprocessor Interface - An Interdata Universal Logic Interface board is adapted to accept the 16-bit plus parity parallel data output from the Data Preprocessor and transferred to 8/32 Processor memory via a dedicated Selector (DMA) channel. This 8/32 Processor hardware complement is supported by an OS/32MT2 operating system and applications programs.

Calibration

Calibration includes the functions necessary to establish the Calibrate Mode in the system and to transfer color sampled data, both ratio values and lightness values to the 8/32 Processor for each color and screen density on the chart. This operation may be performed in either, or both, static or dynamic scanning of color features or areas. The calibration function is shared between the Data Preprocessor and 8/32 Processor with the Control Microprocessor providing the communication link between the two.

Color samples received by the 8/32 Processor are analyzed and color discrimination limits are calculated and sent to the Data Preprocessor via the Control Microprocessor and stored. During the scan the Data Preprocessor compares the scan data against the limits and identifies the colors and screens along the scan line.

B. System Configuration and Major Components

The Color Raster Scanner System is shown in Figure 5. The Color Raster Scanner System consists of seven major equipment units. The equipment units are:

* Scanner Unit
* Vacuum Pump
* Processing Console
* CPU Cabinet
* Carousel 30 Keyboard/Printer
* Graphic Display Terminal
* Magnetic Tape Drives

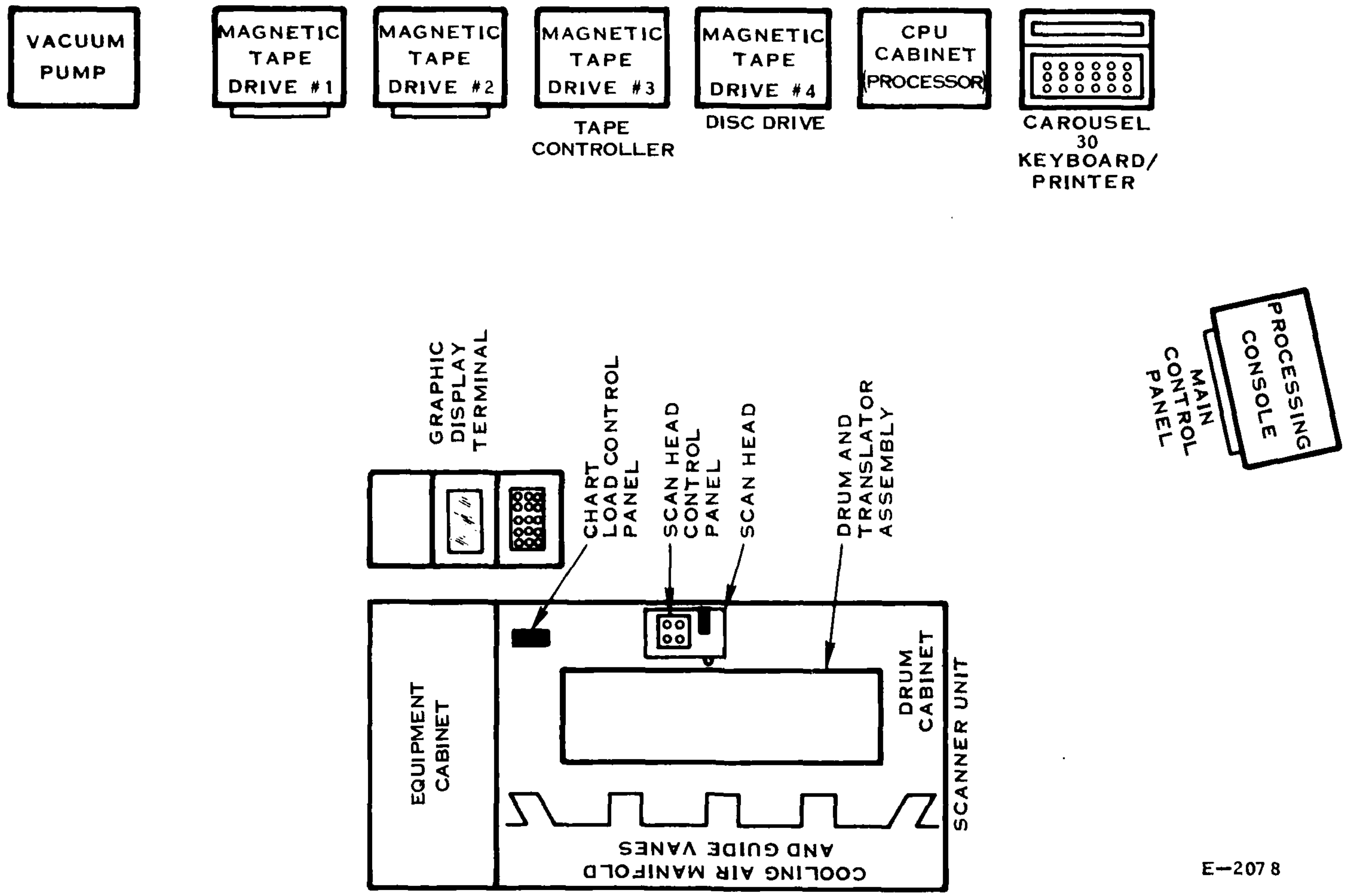


FIGURE 5 COLOR RASTER SCANNER SYSTEM

The Scanner Unit comprises two separate compartments. The larger compartment, the Drum Cabinet, houses the Drum and Translator Assembly and Scan Head. Located at the rear of the Drum Cabinet is the Cooling Air Manifold which circulates air from an external air conditioning system throughout the compartment. The Chart Load Control Panel is positioned to the right of the Drum. The second compartment, the Equipment Cabinet, contains electronic equipment and is accessible for maintenance purposes only.

The Vacuum Pump produces the vacuum necessary for chart hold-down. A hose connects the Vacuum Pump output port to the interior of the hollow Drum. Air is drawn through small holes distributed over the Drum surface creating a pressure differential across the surface sufficient to hold the chart flat against the Drum. The Vacuum Pump may be located remotely.

The Processing Console contains the Data Preprocessor electronics which performs the color discrimination and data compression functions, and the Control Microprocessor which coordinates the Scanner control functions. The Main Control Panel is located at the front of the Processing Console.

The CPU Cabinet houses an Interdata Model 8/32 Processor, memory and associated interface hardware. Adjacent to the CPU Cabinet are four Magnetic Tape Drive Units, designated #1, #2, #3 and #4. The Tape Drive #4 Cabinet holds the 10 megabyte disc (5 megabyte fixed, 5 megabyte removeable). One tape controller is located in the Tape Drive #3 Cabinet; the second is in the I/O chassis.

The Carousel 30 Keyboard/Printer and the Graphic Display Terminal (GDT) are the operator consoles.

The Processor receives the Scanner run-length encoded data output by the Data Preprocessor and transfers the data to magnetic tape in Scan Record Tape format. Subsequent processing of the Scan Record Tapes by the Processor produces Edited Scan Record Tapes with editing, distortion removal, change of scale, merge, etc. functions performed as required.

SECTION III

DRUM SCANNER UNIT

A. Design Approach

The basic design concept of the Drum Scanner Unit was established at the outset to consist of a cylindrical drum, to the outer surface of which chart materials would be attached and held by a partial vacuum developed internally, and an optical sensor unit moved stepwise on an axis parallel to the cylindrical axis of the drum.

Initially, the Drum Scanner Unit design approach was based upon the configuration employed in the Automatic Color Separation Device (ACSD) which had demonstrated a high level of reliability since its installation at RADC in 1968. It was intended to scale-up the ACSD concept of a vertically-oriented drum, mounted in a frame consisting of a base plate, top plate, and three support columns, to accept the larger chart size specified for the Scanner. To meet the tighter accuracy and repeatability requirements of the Scanner, careful design study of machine tolerances would be necessary to define that structure to a greater precision.

During the Scanner design phase the approach to the Drum Scanner Unit shifted from the ACSD vertical design to a horizontal drum orientation. This change was due in the main to three factors that developed during this period. First, in adapting the existing design of the Scan Head positioning mechanism, it was determined that the split column, through which the coupling of the carriage to the ballnut was made, could not be manufactured with confidence of achieving the accuracy of the part as needed in the Scanner. It was, therefore, evident that a signicant amount of redesign in this area was required. The second development was that most shops solicited were not interested in manufacturing the ACSD design within cost constraints; the few that responded affirmatively presented costs that were not economically feasible within existing constraints. As a result of the engineering and cost problems which had developed with the existing vertical drum design, consideration turned to the availability of a horizontal drum unit of existing design capable of meeting the Scanner requirements. This engineering investigation came to a conclusion with the selection of the Concord Control drum unit, equivalent in basic design to the units used in the RADC Raster Finishing Plotters.

B. Description of Drum Unit

The Drum Scanner Unit consists of the following major components:

a.) Drum structure

b.) Ways, leadscrew, and carriage system

c.) Support structure and leveling packs

d.) Electrical limit detectors and positive stops

e.) Leading-edge clamp and vacuum system

f.) Motors, Encoders, and Scan Head mountings.

Figure 6 illustrates the major components of the Scanner Unit.

Drum Structure - The drum is fabricated from a one-inch plate of 6061 aluminum rolled to a nominal outside diameter of 25 3/16 inches. The butt joint was welded by electron-beam. The electron-beam welding operation resulted in an adequate mechanical bond but did not fully fill the joint, and was subsequently filled by hand welding. As a result of the hand welding used to close the drum electronic weld, the unfinished drum deformed inward at the weld. The inward deformation was great enough to prevent the area from being finished in the rough machining operation. An attempt to correct the low spot by additional hand welding caused the drum surface to further warp inward and enlarge the area of depression.

In order to utilize this drum, the leading-edge chart clamp, which establishes the approximate location of the X=0 coordinate, was positioned so the depressed area lies entirely in the inactive scan region; i.e., beyond the 155 cm circumferential position, and has no adverse effect on the scanning accuracy.

The drum was thermally stress relieved and machined inside and outside to a nominal outside diameter of 28 1/8 inches, and a nominal thickness of 5/8 inches with mounting rabbets at both ends. After the final grind operation, the depressed area was built-up with an aluminum filled epoxy putty, and reground to a radius approximately 0.001 inch larger that the finished drum radius. The edges of the patch were feathered by hand, and the entire inactive scan zone of the drum was painted flat white. This area is now about 0.002 inch higher than the active working area. The drum surface in the working area is machined and buffed to a dull bare aluminum finish.

The drum mean outside diameter over the working area was determined by measurement to be 25.035 inches at 68°F. Measurements were made by calibrated micrometer, and by an interferometric calibrated grid produced on a stable film base with temperature and humidity factors and film thickness, taken into account. The mean diameter at any

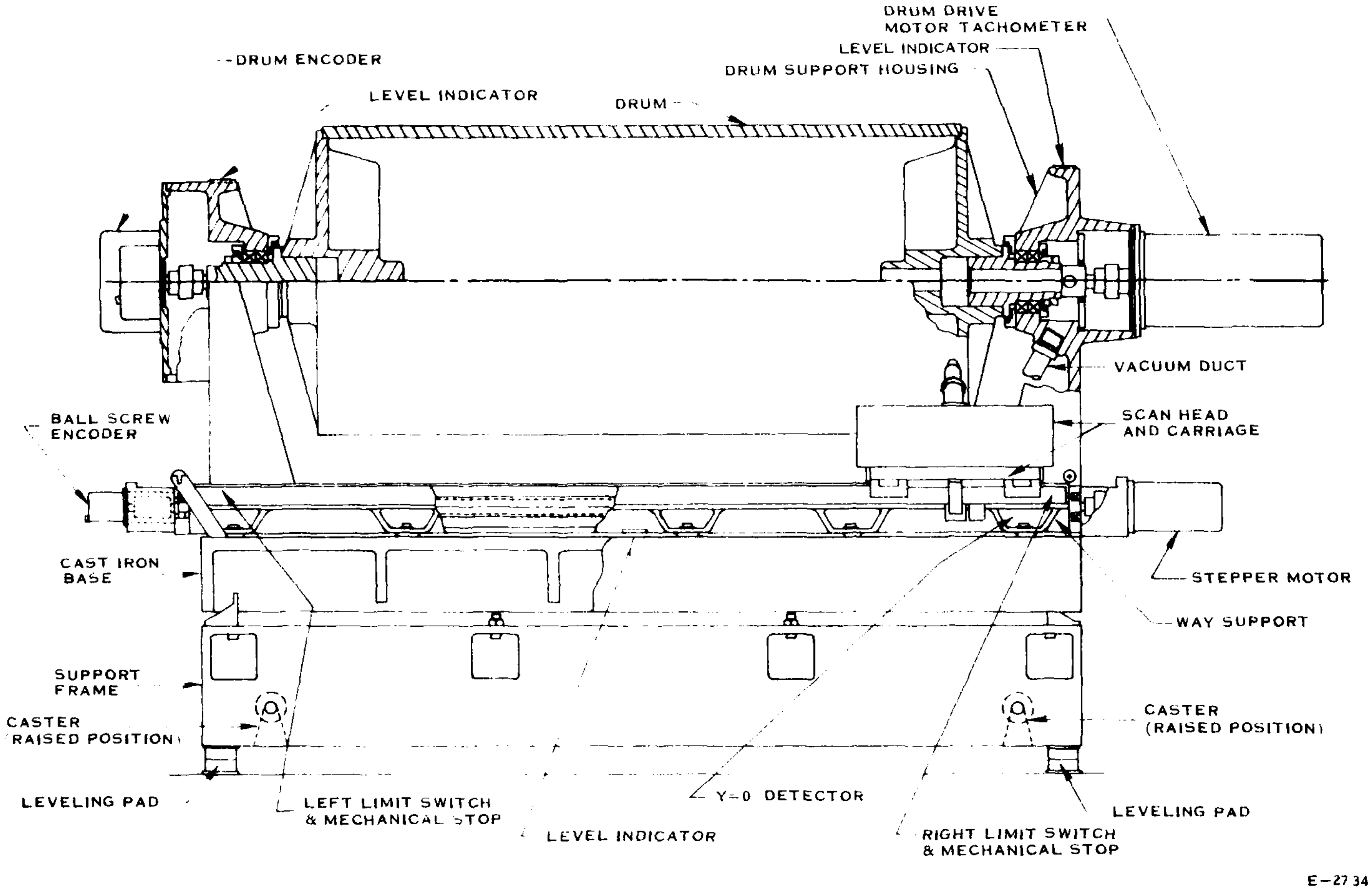


FIGURE 6 DRUM SCANNER UNIT, FRONT VIEW

axial location did not differ from the overall mean by more than about 0.0002 inch. From indicator measurements of the relative drum radius, the average radial runout in the working area was determined to be 0.0002 inch, with the worst measured value 0.00032 inch TIR. The axial length of the drum surface was measured at 53 inches.

The drum is supported by ribbed cast aluminum end plates piloted to the drum mounting rabbets, and pinned and bolted to the drum. The end plates are provided with hardened stainless steel spindles pressed into the end plates and bolted to the plates. The journal areas of the spindles and the drum OD were ground concentric after assembly. A pair of duplex angular contact ball bearings of ABEC7 grade were pressed onto each of the spindles with high spots opposed, and were locked by standard self-locking locknuts. The drum was dynamically balanced after assembly at a speed of 330 rpm. Measured accelerations in the structure and at the bearings, in either horizontal or vertical directions, did not exceed 0.0005g after balancing.

The drum inertia was computed from measurements to be 326 lb. ft^2; starting torque required was measured at 1.53 lb. ft, mean value, and running torque was determined to be about 2.9 lb. ft. at 300 rpm.

Ways, Leadscrew, and Carriage System. The carriage, leadscrew, and ways system are designed to carry loads in excess of 100 lbs. without performance deterioration. In load tests up to that amplitude, the observed maximum vertical deflection of the carriage paths was less than 50 microinches, occurring at the center of travel. Carriage travel between limit switch actuation points is approximately 129 cm.

The leadscrew assembly is a pre-loaded, ball-bearing, screw-nut assembly with a lead of 5mm, pitch diameter of 1.25 inches, and a free working length of 60 inches. The leadscrew is mounted by two pairs of ABEC7 angular-contact pre-loaded ball-bearings mounted with high spots opposed, and clamped to the leadscrew by self-locking locknuts.

The carriage linear travel (Y-coordinate displacement) was measured from Yo to the lefthand end using a HP5526A Laser Measurement System. This measurement was compared to the Y-coordinate position displayed on the Main Control Panel from a count of the motor drive pulses. Over the first half of the ballscrew length, the difference, or error, increased to -0.025mm, and remained within ± 0.013mm of that level for the remaining travel. This result represents a total of all error contributions to the Scan Head carriage displacement.

Measurements of pitch, yaw, and roll of carriage travel alignment showed the carriage track to be straight to within ±200 microinches. In addition, the relative radius of the drum, indicated from the carriage to horizontal and vertical center lines of the drum, and corrected for measured pitch, yaw, and roll displacements, show that the carriage tracks parallel to the drum axis within ± 200 microinches.

Spring-loaded roller-mounted rubberized fabric way covers are provided. Carriage motion is not restricted by the way covers.

Support Structure. The drum supports are of cast aluminum, ribbed and braced, and mounted on a ribbed cast iron base plate. The base plate is supported by a steel frame which rests on four adjustable leveling jacks at the floor. Level glasses are mounted on the two bearing support castings for transverse (carriage roll axis) alignment, and in the front center of the base plate for longitudinal (carriage pitch axis) alignment.

Electrical Limit Detectors and Stops. Electrical limit switches with DPDT, 1 ampere 115 volt contacts are installed at both ends of the carriage track. The activation point is adjustable and has been set at 0.75 inches beyond the working area, and 0.5 inch before the positive stop. The positive stop can absorb a full-speed overrun of the carriage without damage to any component of the system.

An IR source and detector are mounted at the righthand end of carriage travel (motor end) just ahead of the limit switch. In the RESET Y operation, a metal blade mounted to the front of the carriage interrupts the IR beam incident on the photodetector, and initiates the process of stepping the carriage to the Y=0 coordinate position.

Leading-Edge Clamp and Vacuum System. The leading-edge chart clamp is approximately 0.125 inch high above the surface of the drum, and will accommodate chart materials up to 0.030 inch thick.

Vacuum holes are provided on approximately 50 cm centers in both directions over an area of 120 by 150 cm. The turbine vacuum pump supplied produces a negative gage pressure of approximately 0.1 psi in the drum with all vacuum holes open and 50 feet of hose between the pump and the drum. Vacuum passage is provided through the motor-end spindle, and a rotating joint integral to the drum bearing support casting.

Motors, Encoders, and Scan Head Mountings. Drive spindle shafts of 0.75 inch diameter are provided at both ends of the drum. Pilots are provided for the Inland drive motor and the Itek shaft encoder which are connected to the spindles by flexible couplings. Ball-screw shaft ends, mountings, and couplings are provided in the carriage drive system for the Superior Electric stepper motor, and the Trump-Ross shaft encoder. The carriage plate to which the Scan Head is mounted is a 1-inch aluminum plate 11 by 14 inches in size. Mounting surfaces at the front and rear of the plate have been scraped flat and coplanar. Tapped holes and dowel pins are provided for the precise location, and attachment of the head.

SECTION IV

SCAN HEAD

A. Design Approach

The principal function of the Scan Head is to produce continuous electrical signals which are analog representations of the optical reflectance spectra of the graphic material being scanned. From these signals, the Data Preprocessor determines which color, of those on the input source, is present at each element of area, and also determines the type of data present (eventone color, screen or process color).

The implementation of the Scan Head was initially planned to generate the signals required by the Data Preprocessor through the use of three separate spectrum measurements in the visible region, for color identification at resolution scale. In addition, a fourth output signal produced from a slightly larger area of the chart, concentric to the resolution element of area, was to be made to provide a measurement of the total light reflected from the chart. This output, proportional to the reflective density of the graphic data in the area covered, would provide a basis for the discrimination of black and white, area-fill colors of different tone, and screens of different densities. The recognition of screen, as well as process color, was to be based upon their graphic constructions defined to the logic of the Data Preprocessor.

In the design phase, the measurement parameters and the Scan Head implementation, underwent a maturing and change as a result of the study of the requirements of chart data type identification, and the hardware capabilities available for the Data Preprocessor functions. The high-speed microprocessor originally planned to implement the data processing functions was found not to be capable of the task at the data rate necessary to meet the required scan time. This resulted in the change to two sets of light measurements, each set being similar and comprised of three separate spectrum measurements in the visible region. One set being the three resolution-scale spectral primary measurements, and the second being a similar set of spectral primary measurements taken from larger areas on the source for the purpose of color identification of screen or process color chart presentations. That instrumentation concept was designed, developed, and satisfactorily proven-out in the delivered system.

B. Description of Scan Head

The Scan Head is the input unit of the Color Raster Scanner and is located in the Scanner Unit adjacent to the periphery of the drum.

The Head is doweled and fastened to the carriage which is supported on bearings and guided by precision ways. Under software control, the Scan Head is moved in resolution increment steps parallel to the drum axis by a stepper motor drive system.

The Scan Head provides the functions of photodetection of chart information, the conversion of detected signals for transmission to the Data Preprocessor, and the manual controls used by the operator in the chart calibration mode.

The Scan Head was designed and fabricated in two major assemblies; one being the Optical Housing and the other the Lower Housing. The Optical Housing comprises the top of the Scan Head and lifts off of the Lower Housing which is doweled and attached to the carriage.

The Optical Housing contains all components of the illuminator, and the optics system. The illuminator and the collection optics are mounted to the top of the Optical Housing; the internal optics are mounted to the underside of the Optical Housing. The Optical Housing is located to the Lower Housing by dowels and the mating surfaces are sealed by a gasket to avoid light leakage.

The Lower Housing contains the Scan Head Board Assembly, on which six photodetectors and their associated components are installed, and six identical analog driver circuits with their ± 15 VDC power supply. The Lower Housing also includes the electrical connector which carries all electrical signals and power to the Scan Head.

Scan Head photodetection functions consist of:

- Illumination of the chart
- Collection of light reflected from the chart
- Imaging of the area of the chart surface included in the field of the collection optics
- Separation of the collected light into spectral bands (primaries) for chart identification
- Photodetection of each spectral band

The determination of the design approach in each of these functional areas was based upon consideration of the graphic materials to be input to the Scanner, of alternative methods of illumination, of methods of color identification applicable in the high-speed Scanner operation, and of techniques by which screen and process color forms may be recognized. From these studies the design approach was developed in further detail to determine performance which could be expected based on representative source charts. The results of this design phase work are described in the following sections.

The photodetection Subsystem was designed and implemented to provide the basic measurements required by the color identification and the screen recognition concepts which were determined in system design of the Scanner. The concept applied in color identification is that of measuring the amplitude of each of three primaries, or spectral distributions, and forming the ratio of each primary value, separately, to the sum of the three primary values. The three primary ratios, together with a density, or lightness value, obtained as the sum of the three primary values, constitute a description by which each color is identified. In practice, the description becomes a statistical one because of variability in the measurements caused by nonuniformities in the chart.

In the case of screen recognition, the color identification concept employed is the same as that described above; it differs in usage in that the primary measurement is made from a larger area on the surface of the chart such that the measurement is not affected by its position on the screen.

The Photodetection Subsystem includes the provisions necessary to set the size of the chart area to be used in the measurement of the three primaries in the cases of both resolution-size areas and screen-size areas.

In addition to its input measurement functions, the Photodetection Subsystem also provides viewing optics for the operator to be used in precisely establishing points on the chart, and to examine the chart for graphic and color quality.

Figure 7 contains a schematic of the Scan Head optics system. Component spacing is not to scale and the axes have been rotated into one plane to conveniently illustrate all functional components of the unit.

<u>Illuminator</u>

The illuminator used in the Scan Head is a vertical illuminator with the light directed to the chart surface through a concentric annular mirror and condensers surrounding the objective. The illuminator houses a tungsten-halogen reflector lamp. This lamp housing is connected to the objective assembly by an adapter sleeve made of titanium for its low thermal conductivity. A hot mirror is mounted in the path to reflect heat back toward the lamp, and avoid heat build-up in adjacent optics housing. The lamp reflector is a one-piece glass, dichroic coated to transmit infra-red heat rays out through the back of the unit.

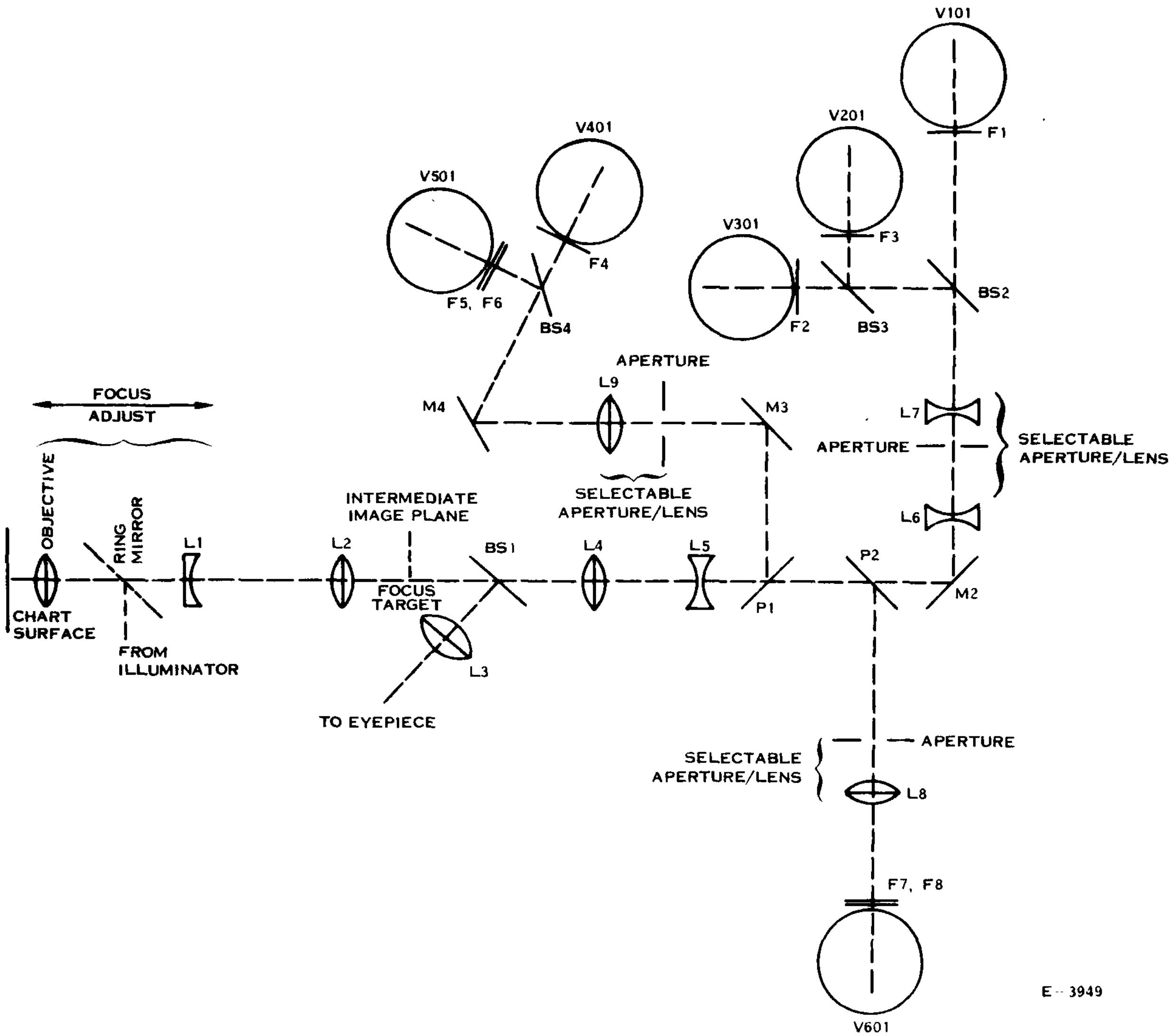


FIGURE 7 SCHEMATIC OF SCAN HEAD OPTICS

The lamp used is a ANSI Code EKE, 150 watts, 21 volts. In application the lamp is run slightly derated to 20 volts d.c. The lamp output under derated conditions has a color temperatore of approximately 3150°K.

Collection Optics

The Collection Optics consist of the objective, lenses L1 and L2, and a focusing target located at the intermediate image plane.

The objective lens is contained in an assembly with the ring mirror and an annular condenser lens. The objective is 6.5X with a numerical aperture of 0.18. Working distance between the end of the objective and the chart surface is about 16 mm when adjusted to produce an image at the intermediate image plane.

Lens L1 is plano-concave, with a negative focal length of -125 mm and is mounted in a Guiding Sleeve within the Objective Support Housing. Lens L1 moves in its mounting, together with the objective, along the center axis of the assembly when the focus ring is rotated. This adjustment is used to focus the chart surface in the intermediate image plane, for any chart thickness, including an underlay, which may be applied to the Scanner. The focusing adjustment maintains the objective at a fixed working distance so that paraxial light rays originating at the chart will emerge from L1 parallel to the optical axis.

Lens L2 is an achromatic doublet with a focal length of 50 mm employed to minimize chromatic aberration in the image that the positive lens produces in the intermediate image plane. With the image focused in the plane of the target, the working distance will be at 16 mm and therefore, the magnification in the image will be fixed.

The image of the chart surface produced by the Collection Optics in the intermediate image plane is real, inverted, and magnified 2.8X.

Relay Optics

The intermediate image is optically relayed to the measurement image planes where it is sampled by selectable apertures, which are related by the magnification of the optics to the areas of measurement at the chart surface.

From the intermediate image plane, the reflected light collected from the chart passes into the space below the Optical Housing, where it is reflected by mirror M1 (not shown in Figure 7) onto the lower optics plane which is horizontal and parallel to the machined surface on the underside of the Housing. M1 is a front surface mirror consisting of a thin opaque layer of aluminum overcoated with several transparent dielectric layers to enhance reflectance; average reflectance is 94% over the visible spectrum.

The next component in the optics path is Beamsplitter BS1 which is positioned so that its surface is at an angle of approximately 60 degrees from the optic axis to reflect part of the light for viewing of the chart by the operator. BS1 is a pellicle; a tough, elastic membrane of nitrocellulose with thickness of 8 micrometers and stretched taut over a circular frame. The pellicle is uncoated and provides a reflectance/transmittance ratio in the visible spectrum of 8/92; 8% of the collected light is reflected to the viewing port, and the remaining 92% is transmitted to the photodetection paths. The pellicle is used in this location to avoid the double image which would be created by the front and back surface reflections from a glass substrate. The pellicle is so thin that the reflections from the two surfaces are essentially superimposed, and the beam remains unperturbed in its passage through the beamsplitter.

From BS1 the main optics path proceeds to lenses L4 and L5. L4 is an achromatic doublet with a focal length of 60 mm and effects the transfer of the image to the measurement aperture planes. The achromat is used to minimize chromatic aberration in the image formed. Lens L5 is mounted in the same subassembly as L4; its purpose is to increase the back focal length of L4. For this function L5 is a negative lens, bi-concave, with a focal length of -500 mm. The L4-L5 combination produces the chart image in the screen (process color) aperture plane.

The path to the screen green and blue primary detectors is by way of reflectance from Pellicle 1 and mirror M3. The mirror M3 is a front surface reflector, identical to M1, used to fold the path as required by the packaging limitations. Pellicle 1 is similar to BS1.

The path to the screen red primary detector is by transmission through Pellicle 1 and reflectance from Pellicle 2. Pellicle 2 is the same as Pellicle 1. The path length from L5 to the red measurement plane is the same as the length from L5 to the green and blue measurement plane.

The light energy from L5 split-off to the screen apertures from the through beam, by Pellicles 1 and 2, is 8% of the energy incident on the pellicle in each case. This division of the available light provides an adequate signal level for the photodetectors. The image produced in the screen measurement apertures is real, erect and magnified by a 5X factor from the sample size at the chart surface.

The larger part of the light energy collected from the chart surface is transmitted through Pellicle 2, reflected at 90 degrees by mirror M2, and is transmitted by lens L6 to the color measurement plane. Mirror M2 is a front surface mirror identical to M1. Negative lens L6 is bi-concave, focal length -40 mm. Its function is to extend the back focal length of the L4, L5 combination so that the image will lie in the color measurement plane. The image produced in the color measurement aperture is real, erect and magnified 10.4X over the sample size at chart scale.

Spectral Separation

From each of the measurement planes, the image which is sampled by the aperture is transmitted via a lens, through spectral filtering, to the photodetectors. The lenses in these paths, downstream of the aperture, are used to confine the divergent beam to the area of the detector photocathode. Each of the three optical paths differ in their implementation of spectral filtering, and are described separately in the following. All paths, however, are provided with a cylinder of identical dimensions having six circular passages each centered at the same radially distance from the axis of the cylinder. Each circular pathway provides for the installation of an aperture plate and a companion lens, as necessary. The cylindrical aperture/lens housings are positionally controlled from the top of the Optical Housing and are located to the optics axis by a spring-loaded dowel pin which engages precisely machined slots in the periphery of the cylinder.

The screen blue and green aperture sample is transmitted by lens L9 and reflected by mirror M4 to beamsplitter BS4. The apertures and lenses installed, as delivered, are as follows:

Knob Position	Aperture Dia. At Chart Scale	Lens L9
1	0.90 mm	f = +1000 mm
2	1.00	f = +300
3	1.15	f = +250
4	1.30	f = +250
5	0.75	open
6	0.75 X 1.50	f = +160

The lenses L9 are specified to insure that the beam incident on the photocathode is substantially smaller in coverage that the area presented. Mirror M4 is a front surface mirror identical to M1.

Beamsplitter BS4 is oriented at 45 degrees to the incident beam; the reflected optical signal is spectrally filtered by F5 and F6 in series to form the measured value of the screen green primary and is detected by phototube V501; the transmitted signal is filtered by F4 to produce the screen blue primary value for detection by V401.

The BS4 beamsplitter is a short wavelength transmitting dichroic filter; cut-off wavelength (50% transmission) is 500 nanometers with a sharpness of 10%. The transmittance in the pass region is a minimum of 80%, and in the background a maximum of 2%. Since there is practically no absorption loss, the transmission plus reflection is essentially 100% at every wavelength.

The filters F5 and F6 are each medium bandpass color filters. F5 has a center wavelength of 540 nanometers; F6 is 560 nanometers. They are used together to obtain a narrower bandpass than either would provide alone, without the secondary transmission peaks which occur in the background wavelength region of a narrow bandpass filter. The halfwidth of these filters is about 20% of their center wavelength.

The filter F4 in the screen blue primary signal path is a short wavelength transmitting color filter. F4 cut-off is at 520 nanometers with a cut-off sharpness of 7%; transmission is 80% or more in the pass region, and less than 4% in the background region.

Filters F4, F5, and F6, as well as all other 90 degree incidence filters used in the Scan Head, are mounted in a holder which is an integral part of each photodetector magnetic shield.

The screen red aperture sample is transmitted by lens L8, directly through filters F7 and F8 in series forming the spectral distribution of the red primary which is detected by phototube V601. The apertures and lenses installed, as delivered, are:

Knob Position	Aperture Dia. At Chart Scale	Lens L8
1	0.90 mm	open
2	1.00	f = +500 mm
3	1.15	f = +250
4	1.30	f = +250
5	0.75	open
6	0.75 X 1.50	f = +135

Lenses L8 refract the emergent ray bundle to reduce its divergence so that it falls within the detector photocathode area.

The filters F7 and F8 are long wavelength transmitting color filters, and have cut-offs at 600 and 580 nanometers, respectively. Cut-off sharpness, and transmission in pass and background wavelength regions is similar to that of the other color filters.

The spectral transmission from the intermediate image plane to each of the screen/process color photodetectors is shown in Figure 8.

The third optical path is the color measurement path with resolution-size aperture samples transmitted by lens L7 to beamsplitter BS2. The color path apertures and lenses provided in the Scan Head as delivered are:

Knob Position	Aperture Dia. At Chart Scale	Lens L7
1	0.025 mm	f = -20 mm
2	0.050	f = -50
3	0.100	open
4	0.033	open
5	0.039	open
6	0.064	open

The lens L7 is used in this location to increase the divergence of the exiting beam so that it will cover a larger area of the photocathode. The axial rays from the aperture are at a much smaller angle relative to the center line of the path, resulting in a smaller area covered on the photocathodes. For the smaller resolution apertures, negative lenses increase the ray angles resulting in larger coverage of the cathode

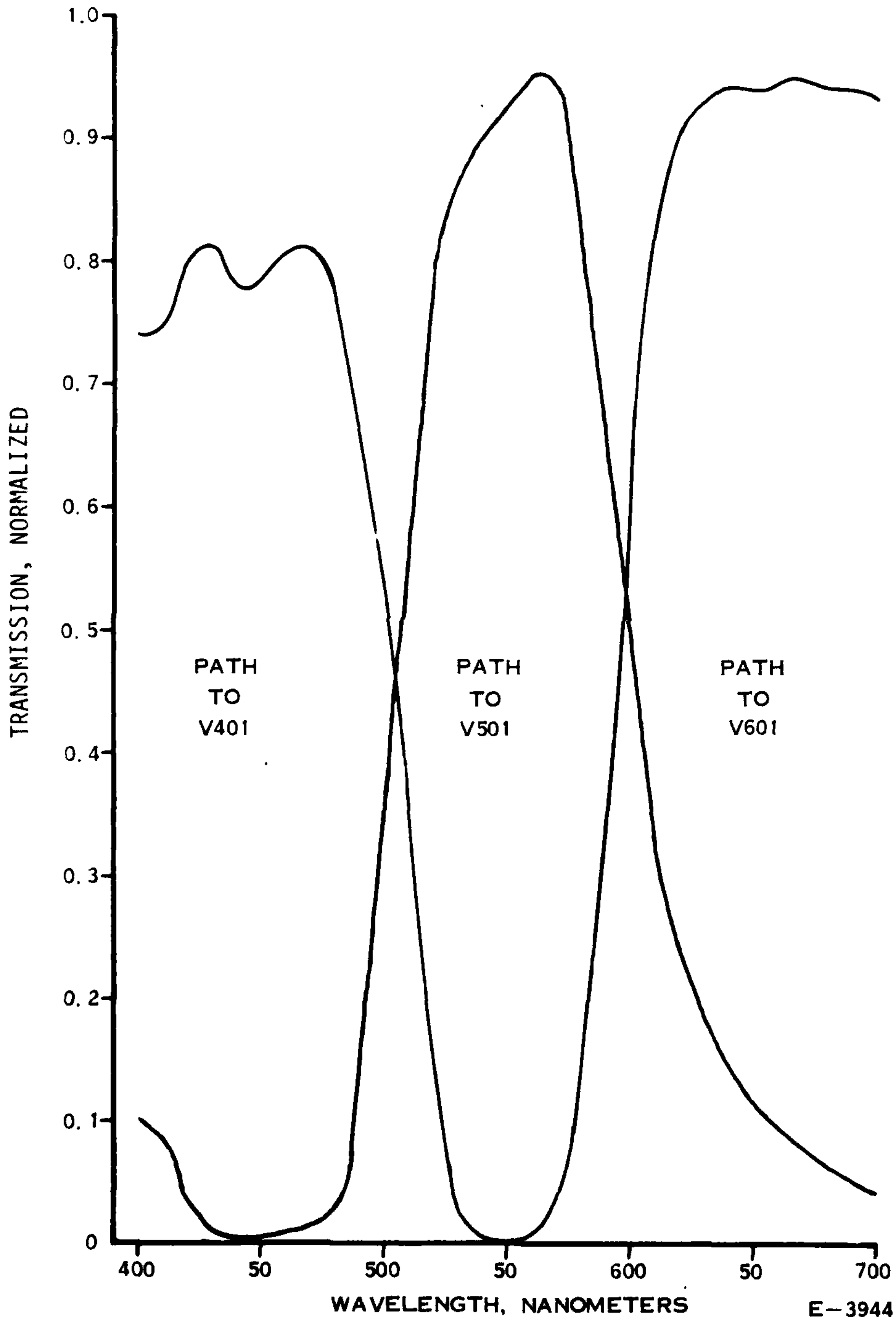


FIGURE 8 SPECTRAL TRANSMISSION THROUGH SCREEN/PROCESS COLOR PATHS

The beamsplitter BS2 is positioned at 45 degrees, reflecting part of the incident light to beamsplitter BS3 and transmitting the remainder to F1 and the phototube V101. The light reaching V101 is the blue primary value of the color measurement. The light reflected by BS2 provides the green and red primary values.

The BS2 splitter is a short wavelength transmitting dichroic filter, similar to BS4, with a cut-off wavelength of 500 nanometers. The blue region of the spectrum transmitted by BS2 is spectrally modified by the filter F1. F1 is a short wavelength transmitting color filter with a cut-off at 520 nanometers and similar to F4 in the screen blue channel.

The reflected part of the beam from BS2 intersects beamsplitter BS3 at a 45 degree angle of incidence. BS3 is a dichroic filter, short wavelength transmitting with 50% transmission (cut-off wavelength) at 600 nanometers. Like the other dichroic beamsplitters cut-off sharpness is approximately 10%, and transmission in the pass region of the spectrum is 80% and a maximum of 2% in the blocking region. Since the large part of the energy in the blue portion of the spectrum has been removed by BS2, the light transmitted by BS3 is mostly green, and the reflected part is red.

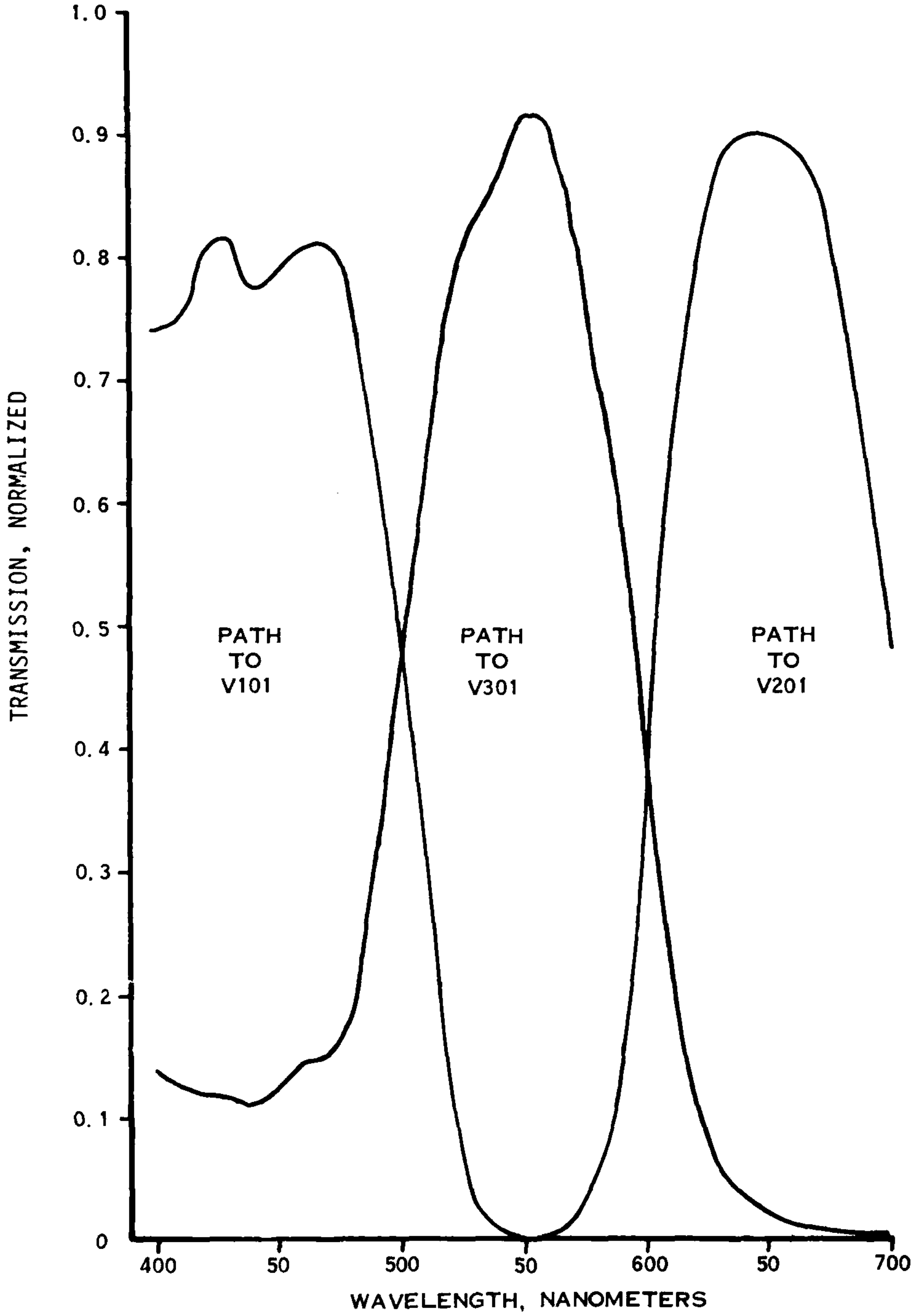
Light reflected by BS3 is filtered by the color filter F3, which is long wavelength transmitting, and has its cut-off at 600 nanometers; it is similar to filter F2 in the screen red channel. The F3 spectral product is the red primary of the color sample measured and is photodetected by tube V201.

The remainder of the resolution color sample, that which is transmitted by BS3 is intercepted by the color filter F2. F2 is a medium band pass filter, centered at 540 nanometers and similar to F5 in the screen green channel. The output from F2 is the green primary of the color measurement and is detected by phototube V301.

The spectral transmission from the intermediate image plane to each of the resolution-scale photodetectors is shown in Figure 9.

Photodetection

The detection of the spectrally separated and filtered light reflected and collected from the chart is performed by the six tubes V101 through V601. These tubes are all identical in type: RCA 4526 Photomultiplier Tube. The 4526 tube is a 10-stage dormer-window type having a multialkali photocathode deposited on a reflective substrate. The substrate results in an increase in the sensitivity of the photocathode by reflecting back any incident light not initially absorbed. The sockets for the 4526 phototubes, are mounted in the Scan Head Board Assembly with the dynode voltage divider resistors, and the magnetic shields.



E–3939

FIGURE 9 SPECTRAL TRANSMISSION TO RESOLUTION PHOTO DETECTORS

SECTION V

HARDWARE DESIGN DESCRIPTION

A. Overview

The hardware design evolved from a study of several possible implementations. The design requirements presented several major obstacles:

1.) Resolution and chart scan time requirements dictated a data acquisition rate approaching 500,000 samples per second.

2.) The total information content of a chart, if encoded on an element by element basis, could exceed 10 billion bits.

3.) Any data compression techniques would need to account for the noise and conversion errors inherent in the optical scanning approach.

These requirements indicated the need for a minicomputer which had extensive DMA and IO handling capability. In addition, incoming data from the chart needed some form of high speed data compression, handled by a separate, high speed dedicated processor. Menial chores, such as switch sensing, indicators, stepper motor control, etc. were delegated to a third processor, an 8-bit system chosen to minimize development time.

The Color Raster Scanner hardware provides for those operational functions which are shown in their simplest form in the block diagram of figure 1. The description of the electronics hardware which is covered in this section follows the flow of the data in the Scan operation. That is, the Drum Scanner Unit, which houses the input elements (Scan Head and data entry panels) of the system, and the ancillary functions of operating control and drive power supplies; and the Processing Console containing the signal processing circuits, analog and digital, which make the color determination, and the system operational control elements, which include the 8080 microprocessor unit.

B. Drum Scanner Unit

Analog Electronics

The analog electronics consists of six identical circuits. Each converts incident light at its photo-multiplier tube to a voltage level compatible with the Data Preprocessor analog front end.

The gain of the circuit is entirely dependent upon the level of the high voltage supply driving the photomultiplier tube. Output of the circuit is tuned for optimum performance for the coaxial cable configuration in the system.

Scan Head Control Panel

The Scan Head Control Panel consists of 13 lighted switches and a dual thumbwheel switch. All lights and switches interface to the Control Microprocessor.

Chart Load Control Panel

The Chart Load Control Panel provides control for the following functions:

1.) Vacuum Pump - on/off control and indicators.

2.) Illuminator - on/off control and indicators.

3.) Photodetector high voltage - on/off control and indicators.

4.) High Voltage Supply level control.

In addition, the panel indicates the RESET-X status as determined by the Control Microprocessor.

Y=0 Detector

The Y=0 Detector detects when the Scan Head reaches the absolute zero position on the translator track. At this position, a metal plate on the Scan Head translator interrupts the Y=0 infrared light source, which is detected by the Y=0 photodetector and conditioned by the Y=0 detect module in the Card Rack. The output of this module is connected to the Digital I/F Card, which signals the 8080 via a differential pair line.

Inland (Drum Drive) Chassis

The Inland Chassis houses the control electronics for the Drum drive motor. It contains the power relay, overcurrent trip, power transformers, and an Inland SM-5015 PWM Switching Amplifier. Its function is to supply the pulse width modulated Drum drive power in response to a low-level analog reference signal.

During the scan the Drum is run at 300 RPM. The Drum speed is controlled by an Inland Motors DC motor/tachmeter Velocity Servo System. The Drum Drive system includes those components necessary

to accelerate the Drum from zero RPM to scan speed, hold the Drum at scan speed and decelerate the Drum to zero speed - each function being commanded by the operator via Main Control Panel switches. Ancillary functions of the Drum Drive system are the protective circuits which prevent the Drum from starting when the Scanner doors are open and shut down the Drum in the event of an overspeed or motor overcurrent or overheating condition. A Drum door locking feature is also provided.

Superior (Stepper Motor Drive) Chassis

The Superior Chassis controls the ball screw stepper motor. It houses a Superior Electric SLO-SYN Translator type TBM 105, which provides all switching sequences needed to drive the SLO-SYN stepper motor in steps.

In addition, the Chassis houses the A.C. contactor for the Vacuum Pump. This contactor provides power to the Vacuum Pump under control of the on-off switches at the Chart Load Control Panel.

Card Rack

The Card Rack houses the analog and digital Drum and stepper motor control and interlock circuitry, miscellaneous interlock and control relays, and the Y position sense circuitry. The analog circuitry is on the Analog I/F Card, the digital circuitry is on the Digital I/F Card, and the relays and Y0 detect module are mounted directly on the card chassis.

Maintenance Panel

The Maintenance Panel provides manual control of the basic Equipment Cabinet functions. Controls allow manual Scan Head step and slew, drum motor control, interlock override, and lamp test. The Equipment Cabinet low voltage power supplies are also controlled at the Maintenance Panel, allowing convenient monitoring and calibration.

C. Processing Console

The Scanner Control Microprocessor and Data Preprocessor electronic systems are located in the Processing Console. The Processing Console front panel, designated the Main Control Panel, is an operator interface. The Test Panel positioned behind the door below the Main Control Panel is a diagnostic interface provided for maintenance purposes. The Processing Console also includes the DC power supplies and AC/DC distribution wiring necessary to power the electronic equipment in the cabinet.

1.) Main Control Panel

The Main Control Panel includes controls, indicators, and displays necessary to control and monitor the scanning job.

2.) Control Microprocessor

The Control Microprocessor is an 8080 microprocessor-based system which performs a complex series of actions required to control various Scanner functions. This frees the 8/32 Processor for more important tasks. The Control Microprocessor operates under command of the control panels and the 8/32. The Control Microprocessor performs any requested actions and notifies the 8/32 Processor of system status. The Control Microprocessor also directly controls the setup and timing of the Data Preprocessor, initiating data transfers from the Data Preprocessor to the 8/32 Processor via the 8/32 Direct Memory (DMA) channel.

The Control Microprocessor:

a.) Monitors all control panel switches, lights the control panel indicators and displays in response to the switch commands, and executes the functions commanded by the switches.

b.) Monitors the Scanner X-position as determined by the X-Position Shaft Encoder and displays the decimal X-Address on the Main Control Panel.

c.) Controls the Scan Head Stepper Motor motion and position in all Scanner manual and automatic operating modes; calculates and displays the decimal Y-Address on the Main Control Panel.

d.) Monitors the Scanner Y-position as determined by the Y-Position Shaft Encoder. The encoder-derived Y-position is used by the 8/32 Processor to check that the Scan Head is advancing properly.

e.) Monitors the Drum Drive status (acceleration, deceleration, scan speed) and controls the Drum Drive displays on the Main Control Panel.

f.) Communicates with the Interdata Model 8/32 Processor via the 8/32 Multiplexor Channel Interface. This communication involves command, status, and data transfers which coordinate Scanner functions.

g.) Loads calibration parameters into the Data Preprocessor and sets up the Data Preprocessor.

h.) Incorporates built-in-test software routines which are provided to validate the operation of the Data Preprocessor.

The Control Microprocessor is implemented using an Intel 8080 Single Board Computer (SBC) system. The microprocessor has both RAM (random access) and EPROM (ultraviolet eraseable read only) memory. Figure 10 shows the physical configuration of the SBC system.

3.) <u>Control Panel Interface</u>

Figure 11 defines the Control Panel Interface.

Switches from each of the three Scanner control panels are input to the Encode and Debounce Logic as discretes. When a switch change of state is detected, a Switch Interrupt is generated and an 8-bit switch code is produced at the 8080 input port address "CC". The Control Microprocessor software responds to the interrupt by reading the switch code and jumping to the routine which executes the action commanded by the depressed switch. The Control Microprocessor software routines prevent a switch-commanded action from taking place if it is disallowed by the current Scanner status.

Lighted indicators associated with the switches, and other panel indicators, are controlled by Control Microprocessor output port address "CC". To light a particular indicator, the Control Microprocessor outputs that indicators code to port "CC". The code is decoded and latched by the Decoding Logic and Driver circuit and the indicator is illuminated.

Several switches and indicators are not interfaced to the Control Microprocessor through the Encode and Debounce Logic and the Decoding Logic and Drivers circuits. These switches and indicators are shown on Figure 11 along with their dedicated I/O port address locations.

The X and Y Address decimal displays are controlled by output ports "CD", "CE" and "EA". Data is sent to output port "CE" two digits at a time and strobed into the latching displays by the outputs of port "CD". Output port "EA" bits 1 and 2, control X and Y Address display blanking.

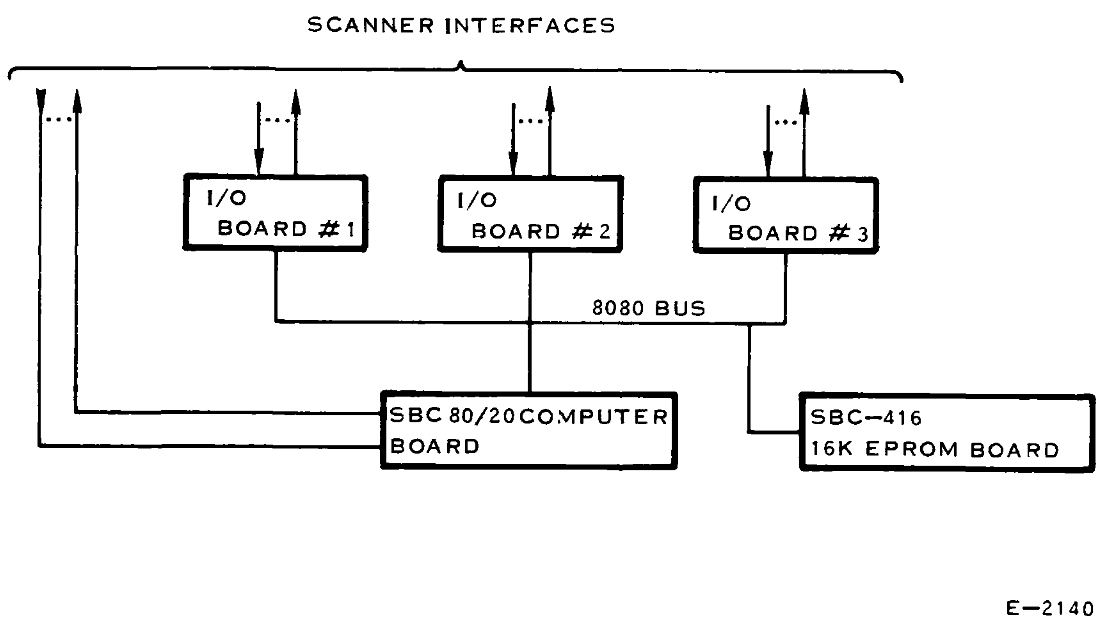


FIGURE 10 CONTROL MICROPROCESSOR CONFIGURATION

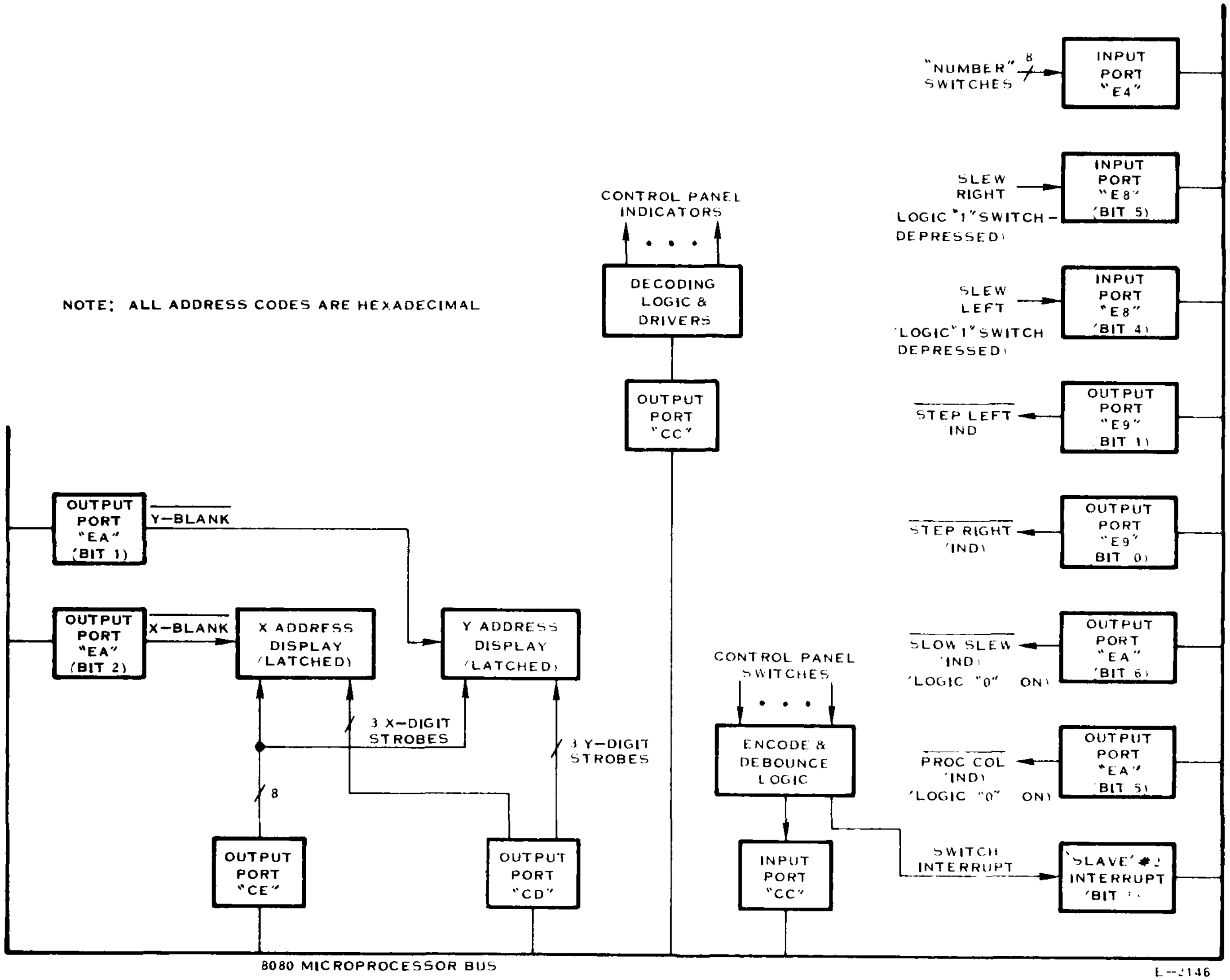


FIGURE 11 CONTROL PANEL INTERFACE

4.) 8/32 Multiplexor Channel Interface

Figure 12 defines the 8/32 Multiplexor Channel Interface. The interface is used to coordinate all 8/32 Processor - 8080 Control Microprocessor activities using the protocol described in the following paragraphs:

8080 Receiver

The 8/32 signals that it is ready to transmit by interrupting the 8080 (8/32 Mux Interrupt). The 8/32 then outputs 16 bits of data and strobes (DAV STROBE) the data into the 8080 MS Byte and LS Byte RCVR Registors. This changes the state of the 8080 Ready Status line to a "0" informing the 8/32 that the 8080 Receiver is "busy." The 8080 software then reads the MS byte RCVR Register. Next, the 8080 software reads the LS byte RCVR Register which returns the 8080 Ready Status line to a "1" condition. Additional words are transmitted to the 8080 using the 8080 Ready Status (no interrupts).

8080 Transmitter

The 8080 outputs data one byte at a time to the 8080 XMTR Register. When the byte is output, a DAV STROBE is produced entering the data into the 8/32 RCVR Register and causing an 8/32 interrupt. The 8/32 Ready Status then signals a Busy condition ("0"). When the 8/32 accepts the data, the 8/32 Ready Status will return to the Ready state ("1").

8080 Status

The 8080 reads the status of its own Receiver and the 8/32 Receiver via the Status Register. ("1" = Ready.) Bit 0 indicates 8/32 status and bit 1 indicates 8080 status.

8080 - 8/32 Protocol

The communication protocol between the 8080 Control Microprocessor and the 8/32 processor is defined in terms of command/control transmission blocks which are sent in both directions between the 8080 and 8/32. Communication between the two machines in initiated at either the 8080 (Control Panels) or 8/32 (GDT) end depending on the transmission type. Each transmission by one machine is acknowledged by the other using a communication protocol which is half duplex. Each command/control transfer sent is acknowledged explicitly by a TRANSMISSION ACKNOWLEDGED, or an 8080 STATUS TRANSMISSION,

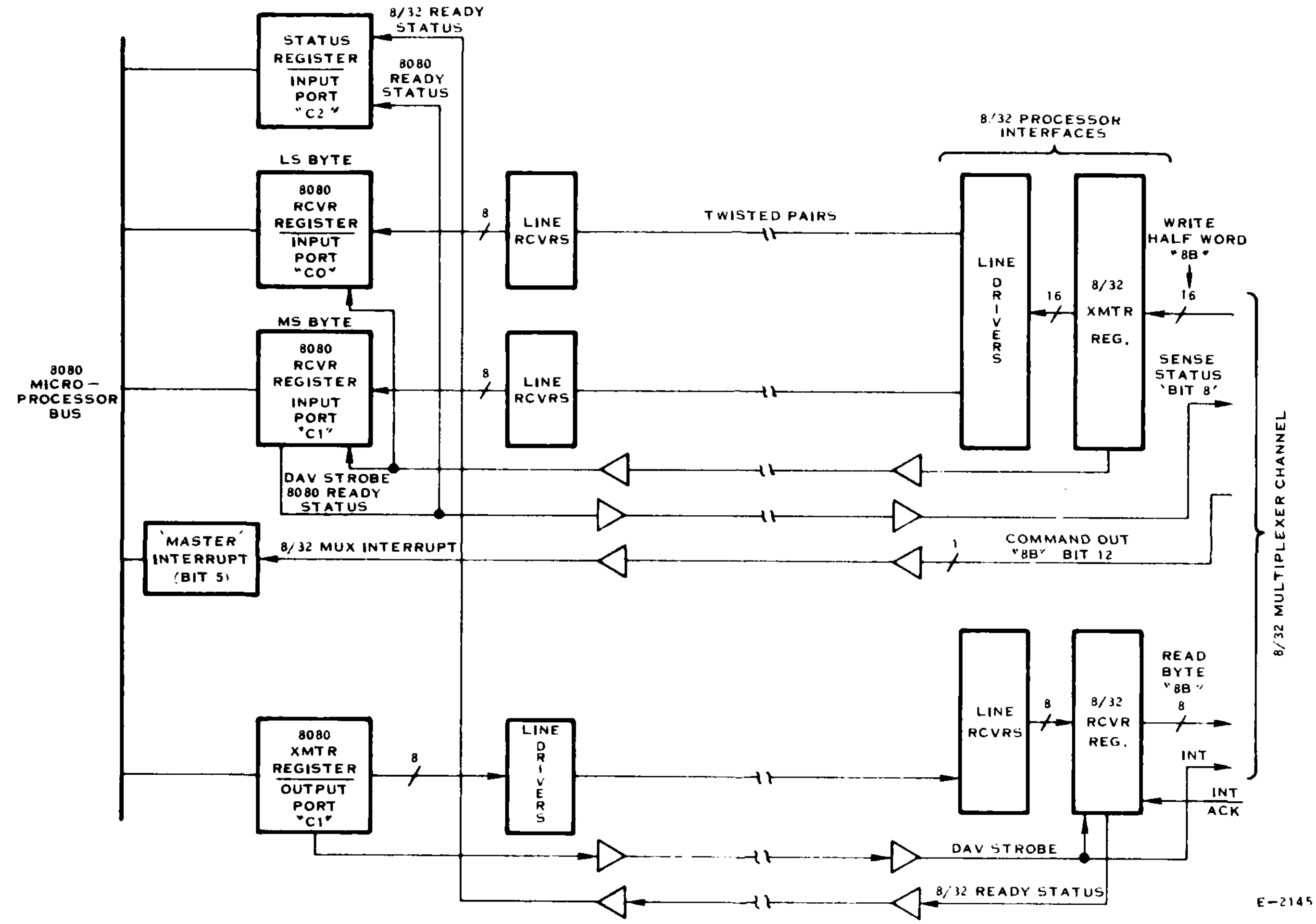


FIGURE 12 8/32 MULTIPLEXER CHANNEL INTERFACE

or by the LAST ID code which is part of the next transmission sent. A (LRC) CHECK SUM included in each transmission is used to check data integrity. The CHECK SUM is calculated by summing all bytes in the transmission discarding overflows. An incorrect LAST ID or a faulty CHECK SUM causes error messages to be displayed and the Scanner operation to be halted. If a CHECK SUM error is detected, transmission retries will be executed before the Scanner is halted and a fault message is displayed.

The basic operating modes of the 8080 Control Microprocessor are determined by control transmission blocks from the 8/32.

5.) X-Position Interface

Figure 13 defines the Scanner X-Position Interface. The Scanner X-position is derived from the ITEK 80,000 pulse per revolution incremental encoder. (X-Position Shaft Encoder)

X-Position Counter

In the Scanner manual operating modes (Chart Load and Calibration), the X-position is maintained by the 0-79999 Binary Up/Down X-Position Counter. The counter is reset by the once-per-revolution "Xo" encoder index pulse.

The output of the counter is transferred to a 24-bit latch when commanded by a strobe generated at 8080 port "B8". The latch is read via input ports "B8", "B9" and "BA". The X-position count is always at the 0.025 mm resolution and is used by the Control Microprocessor software to update the decimal X-Address display and to establish the position of control points which are registered by the operator.

X-Reset Status

Following Scanner turn-on, the operator synchronizes the X-Position Counter with the Drum position by rotating the Drum Paper Guide past the Scan Head Objective. This action produces an encoder Xo index pulse. This pulse sets the X-Reset Status flip-flop and interrupts the Control Microprocessor. After sensing the interrupt, the Control Microprocessor unblanks the X-Address display and displays the current X-position. X-RESET STATUS can also be read at I/O port "E8"-bit 7. (Logic "1" = reset.)

Whenever the Drum is started, the 8080 outputs a "one" at Port "A8". This reinitializes the X-Reset Status flip-flop requiring the operator to resynchronize the Drum when it returns to zero speed.

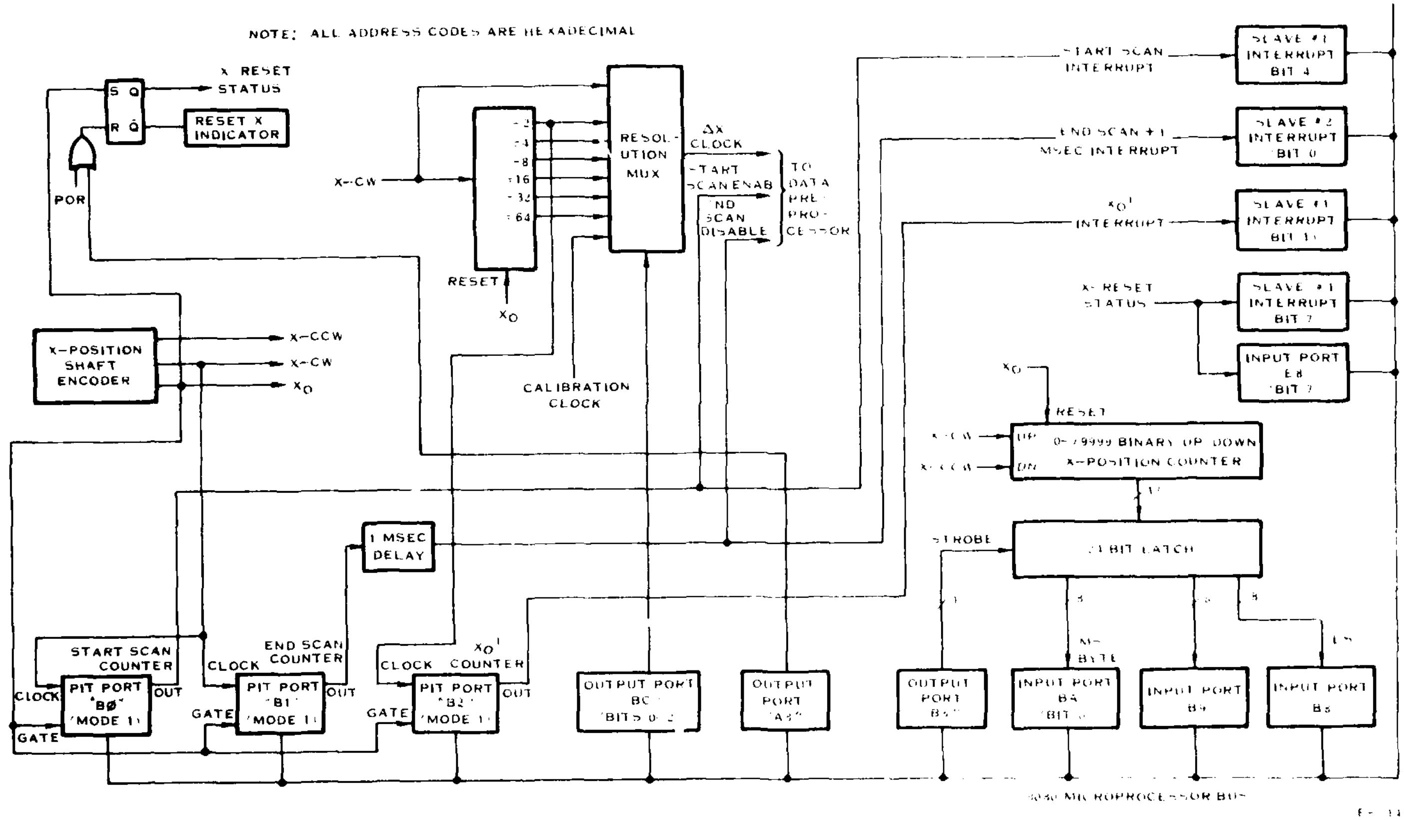


FIGURE 13 X—POSITION INTERFACE

ΔX Clock

The ΔX Clock triggers the Data Preprocessor color-sampling and decision-making operations. The ΔX Clock is derived from the X-Position Shaft Encoder clockwise (X-CW) output. When scanning, the X-CW frequency is 400 KHZ. The X-CW output is divided by 2, 4, 8, 16, 32 and 64; these sub-multiples of X-CW, along with X-CW, are input to the Resolution Mux whose output is the actual ΔX Clock controlling the Data Preprocessor. Microprocessor output port "BC" controls the selection of the ΔX Clock.

For a normal scan at the 0.025 mm resolution, X-CW is selected for the ΔX Clock. At the 0.05 mm and 0.1 mm scanning resolutions, X-CW divided by 2 and X-CW divided by 4, respectively, are selected for the ΔX Clock.

For dynamic calibration, the Resolution Mux is set to select a ΔX Clock which collects a calibration data sample at every eighth 0.025 mm resolution increment.

Static Calibration Clock Generator

The Static Calibration Clock Generator (Figure 14) is selected by the Resolution Mux for static calibration data collection. This circuit transfers a burst of 5 calibration data samples to the 8/32 Processor each time the Scan Head Control Panel STAT CAL pushbutton is depressed. The function is implemented by cross-coupling two 8080 - 8253 Programmable Interval Timer (PIT) peripherals. One PIT, operated in Mode 2, serves as the clock generator. The other PIT, operated in Mode 0, counts the pulses output by the clock generator and controls the total number of pulses produced. In operation PIT port "B6" is preset to 4, PIT port "B5" is preset to 9, and a total of 10 Static Calibration Clock pulses (225 KHZ rate) are produced which causes 5 calibration data samples (ten 16-bit words) to be sent.

Start Scan, End Scan

During normal scan and dynamic calibration, the Start Scan and End Scan Counters control the portion of the scan line over which the Data Preprocessor collects data. These counters are implemented using the 8253 Programmable Interval Timer (PIT) 8080 peripheral operated in Mode 1 (programmable one-shot). Both counters are clocked by the X-Position Shaft Encoder clockwise output (X-CW) and gated by the encoder Xo index pulse.

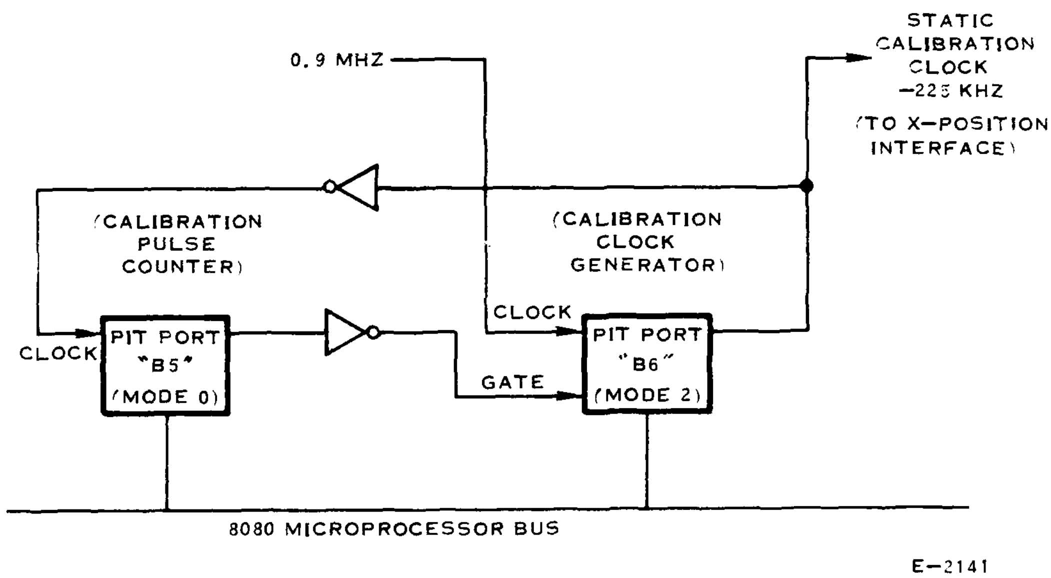


FIGURE 14 STATIC CALIBRATION CLOCK GENERATOR

Prior to the beginning of each scan line, the Control Microprocessor receives a start scan position count, an end scan position count and a scan enable/disable command from the Model 8/32 Processor. (8/32 SCANNING CONTROL BLOCK transmission.) If the scan is to be enabled for the upcoming line, these position counts are loaded into the counters. When the Xo index pulse occurs, the counters begin counting X-CW pulses. At some point the number of X-CW pulses counted by the Start Scan Counter will equal the preset count and the output line of the counter will change state. This enables Data Preprocessor data acquisition. At a later point, the preset End Scan count will be reached and the output of the End Scan Counter will stop the Data Preprocessor data acquisition.

The change of state which occurs at the outputs of the Start Scan and End Scan Counters when their respective preset counts are reached causes the 8080 to be interrupted. The Start Scan Interrupt is used as a check to determine that the scan has been initiated. The End Scan + 1 msec Interrupt (The 1 msec delay is provided to insure that the Data Preprocessor FIFO memory has time to unload at the end of a scan line) is a basic timing marker that the 8080 uses to determine the time at which a transmission to the Model 8/32 may be made during drum operations.

If for a particular scan line the scan is not to be enabled, no count is loaded into the Start Scan Counter. This keeps the Start Scan Counter output in a state which inhibits Data Preprocessor data collection. Because the End Scan + 1 msec Interrupt is used by the 8080 as a basic timing marker to initiate transmissions to the Model 8/32, the End Scan count is preset prior to every scan line (the preset count is 62,000 if the Scan is not enabled for that scan line).

Xo' Counter

The Xo' Counter operates similar to the Start Scan and End Scan Counters, except that this counter is clocked by X-CW divided by 2, and the counter is always preset to 39,800 prior to each scan line. This results in an Xo' Interrupt which occurs approximately 1 millisecond before the beginning of the next scan line is reached and signals the 8080 to make a final determination of whether or not to enable the scan for the upcoming line.

6.) Stepper Motor Interface

The Scan Head is moved by a ballscrew driven by a Superior Electric stepper motor. A Superior Electric Translator controls the phasing of the power pulses to the motor in response to logic level Step Right (clockwise) and Step Left (counterclockwise) inputs to the Translator. For each pulse, the motor moves 0.9^{o} which results in a Scan Head motion of 0.0125 mm.

The Stepper Motor Interface is shown in Figure 15. The interface controls Scan Head motion for Y-Reset, Step (Right, Left), Slew (Slow, Fast), Y-Recover and Auto-Advance Scan Head positioning functions. All required Step Right and Step Left pulses are produced by the 8080 microprocessor in conjunction with three 8080 - 8253 Programmable Interval Timer (PIT) peripheral chips.

The first PIT, designated the Y-Pulse Clock Counter, is operated in Mode 3 (square wave generator) and functions to establish the resolution to which the stepper motor pulse spacing can be set. This PIT is clocked with 0.92 MHZ and is always preset to count of 4 producing a square wave output with a period of 4.38 microseconds.

The second PIT, designated the Y-Pulse Spacing Counter, is operated in Mode 2 (rate generator). This PIT is clocked by the output of the Y-Pulse Clock Counter and is preset to counts which produce the required time intervals between successive motor pulses.

The third PIT, designated the Y-Pulse Width Counter, is operated in Mode 1 (programmable one shot). It is clocked by 0.92 MHZ and preset to a count of 19 resulting in an output pulse 21 microseconds wide each time the PIT is triggered by the Y-Pulse Spacing Counter. Each 21-microsecond pulse interrupts the 8080 (Y-Pulse Interrupt).

To control the stepper motor motion, the 8080 software sets up the Y-Pulse Spacing Counter for the required interval between the first and second pulses to be sent to the motor; when a transition occurs at the output of the Y-Pulse Spacing Counter, the Y-Pulse Width Counter is triggered, and a 21-microsecond wide pulse is sent to the motor. The microprocessor is also interrupted. At this time the 8080 software sets up the Y-Pulse Spacing Counter for the time interval between pulses two and three. At the time the second pulse occurs, the PIT

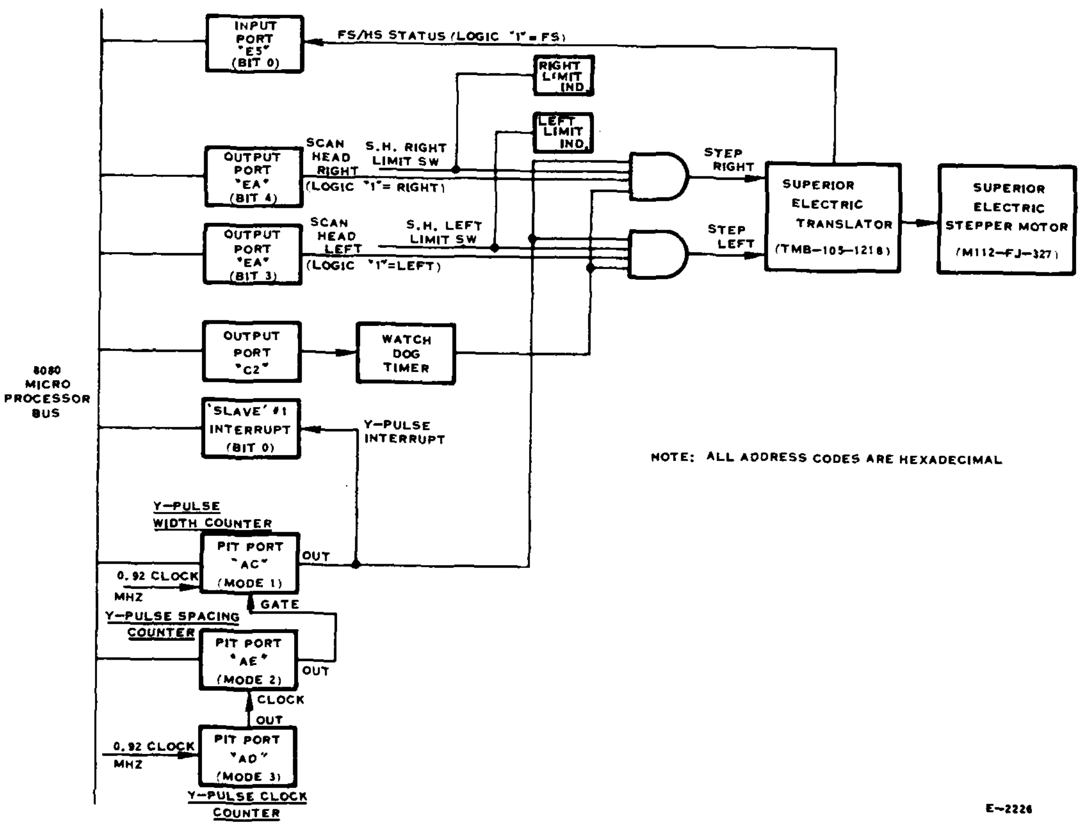


FIGURE 15 STEPPER MOTOR INTERFACE

is preset to provide the required interval between pulses three and four, etc. Thus, to move the motor a predetermined number of steps at a fixed frequency, the 8080 software presets the Y-Pulse Spacing Counter to produce that frequency. The Y-Pulse Interrupts are counted to keep track of the total number of pulses sent and the corresponding Y-position. To accelerate the motor to a high speed, the Y-Pulse Spacing Counter is preset after each pulse to a count which causes the motor pulses to be closer and closer together until the desired slew rate is reached, and the counter is preset to produce the slew frequency. To decelerate the motor the counter is preset after each pulse to spread successive pulses farther apart until the motor can be stopped without loss of position. In all instances, Y-Pulse Interrupts are counted to track Y-position.

Stepper motor direction is controlled by 8080 output port "EA". To step left, bit 3 of the port is set to a logic one; to step right, bit 4 of the port is set to a logic one.

Step Right and Step Left pulses are fed to the motor through AND gates which are enabled only when the Scan Head Right and Scan Head Left limit switches have not been activated. In addition, a Watch Dog Timer, which monitors 8080 program cycle time, must be in a normal condition (i.e., not timed out) before pulses are output to the stepper motor. This additional hardware is provided to prevent the stepper motor from moving in an uncontrolled condition in the event of a Control Microprocessor malfunction. The Watch Dog Timer is set to time out in 800 MSEC if it is not updated by the software.

Step (Right, Left)

The step function is commanded by one of four switches-- two on the Main Control Panel, and two on the Scan Head Control Panel. One switch on each panel is a Step Right switch; the two Step Right switches are wired in parallel so that either switch commands the step right action. "Step Left" is similar.

For each depression of a Step switch, Step Right or Step Left pulses are sent to the motor as follows:

0.025 mm resolution selected - 2 pulses (225 HZ rate)

0.05 mm resolution selected - 4 pulses (225 HZ rate)

0.1 mm resolution selected - 8 pulses (225 HZ rate)

The specified number of pulses move the Scan Head one increment of the selected resolution.

Slew (Right, Left)

The slew function is commanded by one of 4 switches--two on the Scan Head Control Panel, and two on the Main Control Panel.

One switch on each panel is a Slew Right switch; the two Slew Right switches are wired in paralled so that either switch commands a Slew Right. The Slew Left is similar.

The Slew Right or Left input commands a rapid translation of the scan carriage in the indicated direction. The Scan Carriage is moved by outputting a series of Step Right or Step Left control pulses at a high frequency (1657 HZ).

However, the motor will not start and hold synchronization with input pulses at that rate, so it is necessary to start the pulse train at a slow frequency and increase the rate as the motor picks up speed. An acceleration schedule is used to produce a variable spacing between successive pulses.

The carriage will slew as long as the Slew (Right or Left) command is present and will stop when it is removed. However, if the motor is running at high speed and the pulses are abruptly discontinued, the stored energy of the rotating masses will cause the motor to overshoot and lose synchronization. To slow the motor, the Step Right or Step Left control pulses are spaced further and further apart until the motor has decelerated to a speed where it can be stopped without loss of synchronism. The deceleration schedule is the inverse of the acceleration schedule.

For actuations of a SLEW switch which last only an instant, the complete accleration schedule followed by the complete deceleration schedule is commanded so that the motor does not lose synchronism by abruptly stopping.

Slow Slew

When the Scan Head Control Panel Slow Slew switch is in the depressed condition, and a Slew switch is pressed, the stepper motor is moved by outputting a series of Step Right or Step Left control pulses at a fixed 300 HZ rate. No acceleration or deceleration schedule is used.

8/32 Commanded Y-Recover

Prior to a normal scan, and during the dynamic calibration and chartlet scan operations, the 8/32 commands the 8080 to execute a Y-Recover to a specified address. The Y-Recover function positions the Scan Head at the scan line where scanning is to begin, or to resume.

When the 8080 receives a Y-Recover command, the present Scan Head position is compared with the commanded position and the number of stepper motor pulses required to reach the new position, and the direction are calculated. The 8080 then slews the stepper motor to the desired position; acceleration and deceleration schedules are prefixed and appended to the slew to keep the motor in synchronism during start-up and slow-down.

If the number of pulses required to reposition the Scan Head is less than a complete acceleration-deceleration schedule, the stepper motor is commanded to the new position at a fixed 300 HZ rate.

Auto Advance

The stepper motor is controlled in the Auto Advance Mode during the regular scan operations when the 8/32 commands the 8080 to advance the Scan Head at the end of each scan line. (8/32 SCANNING CONTROL BLOCK) The 8/32 sends the 8080 the Number, N, of pulses to be supplied to the stepper motor. From one to eight steps are commanded. Auto advance Scan Head motion is always to the left.

A stepper motor is an underdamped second order system (analogous to a spring-mass system) which tends to overshoot and oscillate about its final position. When the Scan Head is advanced at each scan line, this overshoot must be minimized to maintain the Scanner accuracy. To minimize overshoot and oscillation, two techniques are used. The first technique is to step the motor at the rate, which for that particular number of pulses, causes the motor to reach its final equilibrium position in minimum time with minimum overshoot. The second technique (used for one, two, or three pulses) is called backphasing.

Backphasing is accomplished by sending the motor two additional pulses following the last normal position-commanding pulse.

The first "backphasing" pulse commands the motor to reverse direction (braking the motor), and it is timed to occur before the motor reaches its final equilibrium position. The second "holding" pulse is timed to occur just as the motor "slides into" its final equilibrium position, thus locking the motor at that position.

Motor control is complicated by the fact that the stepper motor is operated in a "half step" mode which for alternate steps energizes one and two motor windings, respectively. With half step operation the motor torque (and dynamic characteristic) is different at alternate half steps. Thus, there are two motor control timing requirements: One for the case where the last motor half step in a sequence of half steps is a two-winding step (designated FS), and the other for the case where the last motor half step in a sequence of half steps is a one-winding step (designated HS).

Motor control timing requirements are stored as 8080 software constants; the correct sequence of pulses is output by 8080 control of the Y-Pulse Spacing Counter, and the Scan Head Right and Scan Head Left lines. In addition, a FS/HS Status Line (input port "E5" - bit 0) is read by the 8080 prior to stepping to determine whether the motor is at a one-winding or a two-winding condition. The motor control required is determined by the 8080, prior to commanding the motor to move, as follows:

a.) If FS = "1" (two windings energized) and an even number of half steps is to be commanded - use "two-winding" (FS) control.

b.) If FS = "0" (one winding energized) and an odd number of half steps is to be commanded - use "two-winding" (FS) control.

c.) If FS = "1" and an odd number of half steps is to be commanded - use "one-winding" control.

d.) If FS = "0" and an even number of half steps is to be commanded - use "one-winding" control.

<u>Y-Reset</u>

When the RESET Y pushbutton is depressed, the 8080 turns on the RESET Y indicator and executes a routine to find the Scanner Y=0 absolute origin position. First, the Y-Reset Enable

(output port "BD" - bit 0) is set to the enable state. Then the stepper motor is slewed right until:

a.) A Y=0 Interrupt occurs, or

b.) A Scan Head Right Limit Switch Interrupt occurs.

In case (1) the Scan Head started to the left of the Y=0 position, and a deceleration to zero speed is commanded as soon as the Y=0 Interrupt occurs. When the stepper motor has stopped, it is stepped left 75 pulses at a 300 HZ rate. Then, it is stepped left one step at a time with pulses supplied at a 10 HZ rate.

Stepping continues until the Y=0 Interrupt occurs a second time. At this point the motor advance is stopped, the 8080 maintained Y position (stored in RAM memory) is set to zero and a "0" decimal Y-address is displayed at the Main Control Panel. The RESET Y pushbutton indicator is turned off, and the Y-Reset Enable is turned off. (No further Y=0 Interrupts occur).

In case (2) the Scan Head was to the right of Y=0, and the slew ran the Scan Head into the limit switch. When the Scan Head reaches the right limit switch, a slew left is commanded (with acceleration). When Y=0 interrupts the 8080 a second time, a deceleration is commanded. The Scan Head is now left of Y=0, and the sequence described in (1) above is executed by the 8080.

Notes:

a.) When Y-Reset slewing is in progress, a second depression of the Reset Y switch will stop the slewing action.

b.) Whenever Y is not reset the STEP and SLEW functions are inhibited.

c.) If the Y-Reset function has previously been accomplished, and the RESET Y switch is depressed, the Y-address is blanked and the Y reset routine is executed.

7.) Y-Position Interface

The Y-Position Interface includes the circuitry required for Y=0 position determination, Scan Head right and left limit

detection, and Y-position encoder interfacing with the 8080 microprocessor. Refer to Figure 16 for the following discussion:

Y=0 Determination

The Y=0 position is established by the coincidence of the Y=0 (optical) Detector signal and the Zero Index pulse from the Y-Position Shaft Encoder. The Zero Index pulse occurs every resolution of the lead screw (every 400 net motor steps). The Y=0 Detector signal occurs only near the Y=0 position and is quite broad, overlapping several hundred motor step positions. However, there is one and only one Zero Index pulse which falls within the position where the Y=0 Detector is active. This coincidence of the Y=0 Detector and the Zero Index establishes a Y=0 position repeatable to an exact motor step position. When the Reset Y function is commanded by pressing the RESET Y pushbutton, the Y Reset Enable signal (output port "BD" - bit 0) is activated allowing the coincidence of the Y=0 Detector and the Zero Index to interrupt the 8080 microprocessor.

Y Address Display

Once the Reset Y function has been accomplished, the 8080 maintains the Y position by keeping a count (in RAM memory) of the total (STEP LEFT minus STEP RIGHT) pulses supplied to the stepper motor. This count is factored for the selected Scanner resolution (i.e., divided by 2, 4, or 8 for 0.025, 0.05 and 0.1 mm, respectively), converted to decimal and displayed on the Main Control Panel. Before Y has been reset, the display is blanked.

Scan Limits

If the Y address is established (i.e., Y is reset), the stepper motor is inhibited by the 8080 software before the Scan Head runs into the left or right limit switch. The motor is inhibited before motor position counts of -00300 and 100400, at 0.0125 mm per count, are reached at the left and right extremes of travel, respectively.

If the Scan Head were to move beyond the software limits, the Scan Head Right and Scan Head Left Limit switches will inhibit any further pulses to the motor.

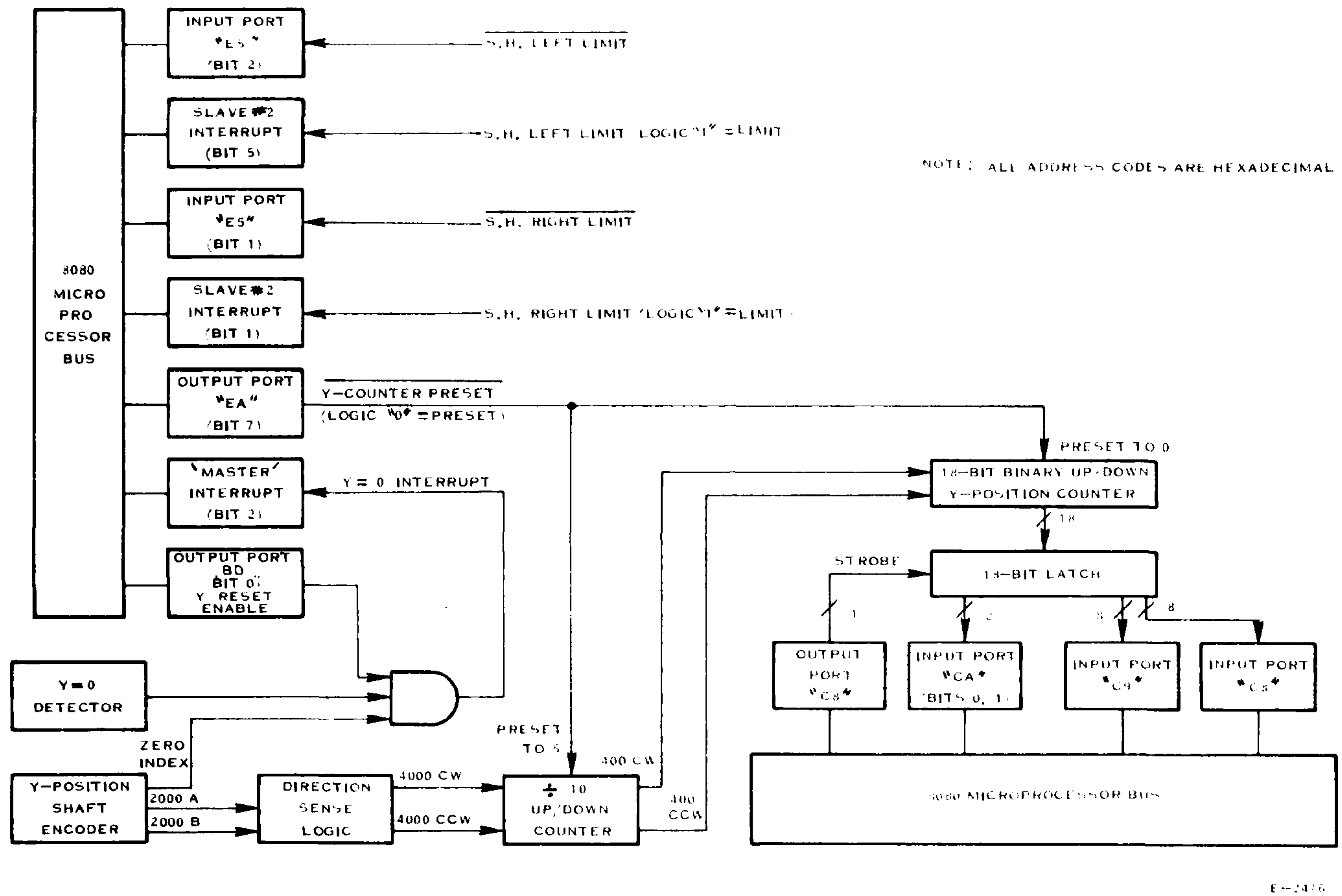


FIGURE 16 Y-POSITION INTERFACE

Input port "E5" bits 1 and 2, and Slave #2 interrupt bits 1 and 5 are used by the 8080 software to determine the status of the Scan Head Left and Right Limit switches.

Y-Position Encoder Feedback

The 2000 pulse/revolution Y-Position Shaft Encoder is connected directly to the ballscrew. The encoder pulse output is input to the Y-Position Interface which converts the encoder pulses to a count which the 8080 can read as a check that each motor pulse commanded has resulted in an increment of motor motion. The components of the encoder interface are the Direction Sense Logic, the Divide-By-10 Up/Down Counter, the 18-bit Binary Up/Down Y-Position Counter, the 18-bit Latch, and the 8080 input ports.

The Direction Sense Logic converts the 2000 pulse per revolution encoder quadrature signals 2000A and 2000B to the 4000 pulse per revolution clockwise and counterclockwise signals 4000 CW and 4000 CCW. 2000B leads 2000A for clockwise rotation viewed from the shaft end. 4000 CW and 4000 CCW are input to a Divide-By-10 Up/Down Counter which has outputs 400 CW and 400 CCW. Each motor step results in a 400 CW or 400 CCW pulse; the pulse which occurs depends on the direction of the motor step. The 18-Bit Binary Up/Down Y-Position Counter maintains a net count (400 CCW minus 400 CW) of the total number of pulses which have occurred. After each motor positioning sequence (allowing 100 milliseconds for all transients to settle), the 8080 reads the Y-Position Counter. The count is transferred to the 8/32 Processor with the 8080 RAM memory maintained motor position in an 8080 Scanning Control Block transmission. The 8/32 determines that the two measured motor positions are identical. The Y-Position Counter is read by strobing (output port "C8") the count into the 18-Bit Latch and reading the latch via input ports "C8", "C9" and "CA".

The Y-Position Counter is synchronized with the 8080 maintained motor position when the Reset Y function is executed. When the 8080 has found the Y=0 position as indicated by the occurrence of the Y=0 Interrupt, the motor is stopped and the 8080 sets its internally maintained stepper motor position to zero. A Y-Counter Preset is then commanded (output port 'EA' - bit 7) which presets the Y-Position Counter to zero and the Divide-By-10 Up/Down Counter to five. The 8080 maintained position and the Y-Position Counter are now in

synchronism and will remain in synchronism as long as the stepper motor follows each step command.

The Divide-By-10 Up/Down Counter is initially preset to five to assure that each 400 CW or 400 CCW pulse occurs halfway through a motor increment and that the Y-position count at each motor rest position is stable and unique.

8.) Data Preprocessor Interface

The Data Preprocessor Interface is shown in Figure 17.

Color (Screen) Encode Parameters

The color and screen discrimination limits are calculated by the 8/32 Processor and transferred to the 8080 with the RECEIVE CALIBRATION PARAMETERS COMMAND where they are stored. The 8-bit limit parameters are:

Red Ratio High Limit Red Ratio Low Limit	seven sets of limits
Green Ratio High Limit Green Ratio Low Limit	seven sets of limits
Blue Ratio High Limit Blue Ratio Low Limit	seven sets of limits
Lightness High Limit Lightness Low Limit	seven sets of limits
SCR Red High Limit SCR Red Low Limit	seven sets of limits
SCR Green High Limit SCR Green Low Limit	seven sets of limits
SCR Blue High Limit SCR Blue Low Limit	seven sets of limits
SCR Lightness High Limit SCR Lightness Low Limit	seven sets of limits

The 8-bit high/low limits are used by the 8080 to format color encoding data words for the Data Preprocessor color encode RAMS. Figure 18 shows the relationship between the high/low limits and the data words which are stored in the RAMS. Data written into the RAMS is read back for error detection.

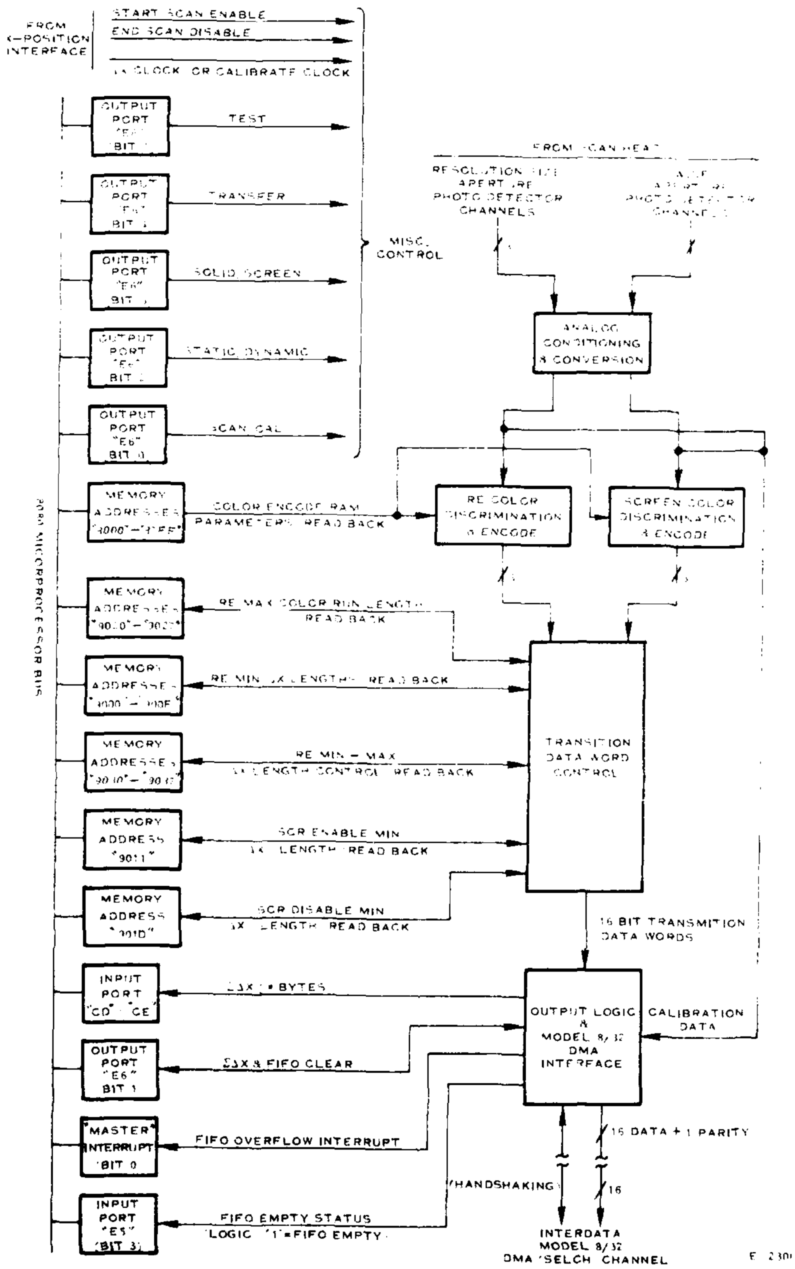


FIGURE 17 DATA PREPROCESSOR INTERFACE

RAM ADDRESS (DECIMAL)

255	254	253	252	251	250	249		5	4	3	2	1	0	
0	0	0	0	0	0	0	. . .	0	0	0	0	0	0	RAM DATA BIT 7
														RAM DATA BIT 6 (COLOR 7)
														RAM DATA BIT 5 (COLOR 6)
	(ETC.)													RAM DATA BIT 4 (COLOR 5)
														RAM DATA BIT 3 (COLOR 4)
0	1	1	1	1	1	1	. . .	1	0	0	0	0	0	RAM DATA BIT 2 (COLOR 3)
0	0	0	0	0	0	1	. . .	1	1	1	1	0	0	RAM DATA BIT 1 (COLOR 2)
0	0	0	0	1	1	1	. . .	1	1	1	0	0	0	RAM DATA BIT 0 (COLOR 1)

→| COLOR 1 "IN LIMIT" ADDRESSES |←

→| COLOR 2 "IN LIMIT" ADDRESSES |←

→| COLOR 3 "IN LIMIT" ADDRESSES |←

"ONES" WHERE: LOWER LIMIT $\leq$ RAM ADDRESS $\leq$ UPPER LIMIT

"ZEROS" WHERE: RAM ADDRESS $<$ LOWER LIMIT

$>$ UPPER LIMIT

Note: Example illustrates RAM storage of one color (or screen) parameter for each color calibrated (3 colors shown)

FIGURE 18 COLOR ENCODE RAM DATA (EXAMPLE)

Hardware Minimum Span/Void Control Parameters

All parameters are entered by the operator at the GDT and transferred to the 8080 with the RECEIVE CALIBRATION PARAMETERS COMMAND. The 8080 transfers these parameters to RAM and reads them back to check data integrity.

a.) RE Min Δ X Lengths

Group 0* - Color 0
Color 1
2
3
4
5
6
Group 0 - Color 7

All parameters are set in the range of 1 tO 15

Group 1* - Color 0
1
2
3
4
5
6
Group 1 - Color 7

*Group 0 = "line" color

Group 1 = "area" color

b.) RE Min Δ X Length Control

PARAMETER

RE Max Color Run Length Control - RAM Bit 0 ("1" Disables Function)	RE Min Δ X Length Control - RAM Bit 1 ("0" Group 0) ("1" Group 1)
Color 0	Color 0
Color 1	Color 1
Color 2	Color 2
Color 3	Color 3
Color 4	Color 4
Color 5	Color 5
Color 6	Color 6
Color 7	Color 7

Screen (Process Color) Control

All parameters are entered by the operator at the GDT and transferred to the 8080 with the RECEIVE CALIBRATION PARAMETERS COMMAND. The 8080 transfers these parameters to RAM. All parameters are read back to check data integrity.

a.) SCR Disable Min ΔX Length

Parameter is set in the range of 2 to 255.

b.) SCR Enable Min ΔX Length

Parameter is set in the range of 2 to 255.

c.) RE Max Color Run Length Limits

PARAMETER	
Color 0	
Color 1	All parameters
Color 2	are set in the
Color 3	range of 2 to 225
Color 4	
Color 5	
Color 6	
Color 7	

$\Sigma\Delta$X

The $\Sigma\Delta$X interface is used to read the 16-bit $\Sigma\Delta$X registers in the Data Preprocessor at the end of each scan line and after a static or dynamic calibration data transfer. The data in the $\Sigma\Delta$X registers is as follows:

Normal Scanning - Total number of resolution elements in scan line (at selected resolution).

Static or Dynamic Cal - Total number of calibration data bytes transferred.

Miscellaneous Control and Status

Data Preprocessor control and status signals are summarized below:

a.) Control (Output port "E6")

SIGNAL	BIT	LOGIC STATE	MEANING
Scan/Cal	0	0	Set Pre-Proc to Cal Mode
		1	Set Pre-Proc to Scan Mode
$\Sigma\Delta$X & FIFO Clear	1	0	Clear $\Sigma\Delta$X Register & FIFO
		1	Normal
Static/ Dynamic	2	0	Set Pre-Proc to Static Mode
		1	Set Pre-Proc to Dynamic Mode
Solid/ Screen	3	0	Set Pre-Proc for Solid Color Cal Data Transfer
		1	Set Pre-Proc for Screen Cal Data Transfer
Transfer	4	0	Inhibit Preprocessor Data Transfer
		1	Enable Preprocessor Data Transfer
	5		Not Used
	6		Not Used
Test	7	0	Set Pre-Proc Normal Mode
		1	Set Pre-Proc Test Mode

b.) Status (or interrupt)

SIGNAL	INTERFACE	LOGIC STATE	MEANING
FIFO Empty Status	Input port "E5" - bit 3	0 1	FIFO Not Empty FIFO Empty
FIFO Overflow Interrupt	Master Interrupt	0	Normal
	bit 0 (Highest Priority)	1	Interrupt

Other

The START SCAN ENABLE, END SCAN ENABLE and $\Sigma\Delta X$ CLOCK Signals shown in Figure 17 are described under the X-Position Interface.

9.) Drum Drive Interface

The Drum Drive Interface is shown in Figure 19. The Drum is controlled by the relays K1 - K2 - K3. The sole function of the interface is to monitor the status of the K1 and K2 relays to light the Main Control Panel Drum Drive indicators and control the Reset X function. The Truth Table for lighting the indicators is as follows

Drum Drive Status			Light Indicator
$\overline{\text{Drum Drive K1}}$	$\overline{\text{Drum Drive K2}}$	$\overline{\text{Scan Speed}}$ Discrete	
1	1	1	OFF
0	0	1	ON - ACCEL
0	0	0	ON - SCAN SPEED
0	1	0	ON - DECEL
0	1	1	ON - DECEL

Miscellaneous Control Status

Miscellaneous control/status functions are shown in Figure 20.

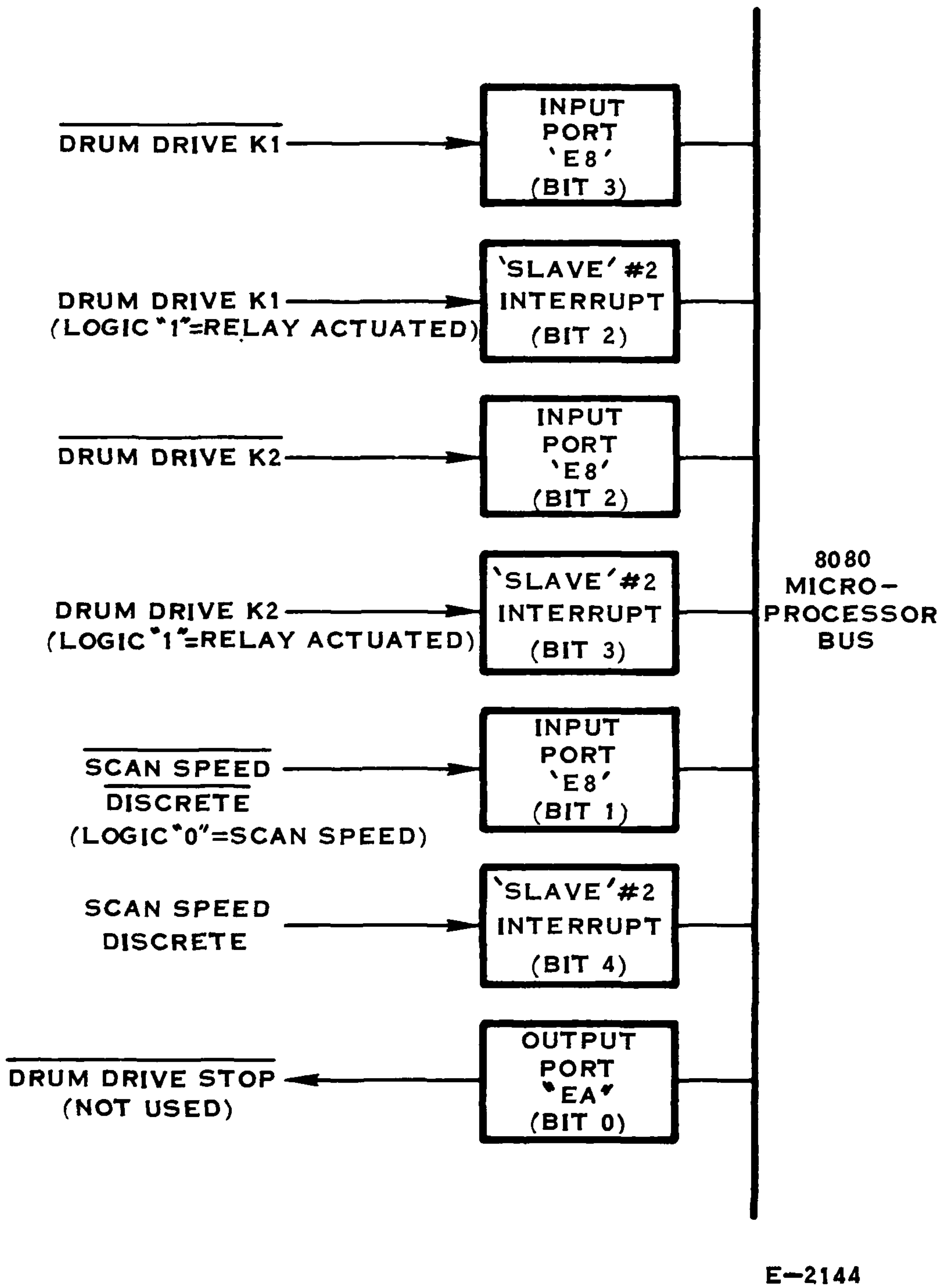


FIGURE 19 DRUM DRIVE INTERFACE

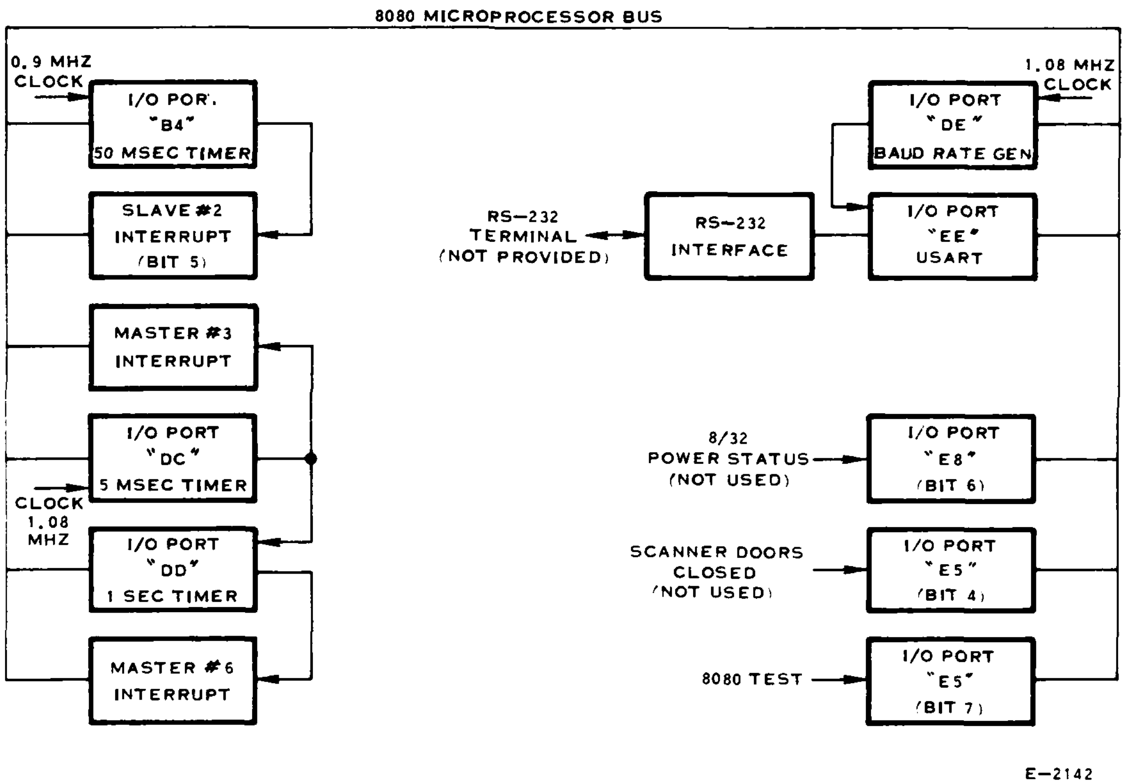


FIGURE 20 MISCELLANEOUS CONTROL/STATUS

a.) Timers

Three timers (5 Msec, 50 Msec, and 1 sec) are used by the 8080 program to schedule events.

b.) RS-232 Interface

An RS-232 Interface is provided for test purposes. When a Terminal is connected to this interface, test routines built into the 8080 PROM program can be accessed to expedite diagnosis of Scanner faults.

c.) 8080 Test (Beno) Switch

When the 8080 Test Switch is set to the test position, the diagnostic test routines stored in PROM memory can be accessed.

0.) Data Preprocessor Functional Description

The basic function of the Data Preprocessor is to detect five colors plus black and white, recognize the presence of screen (or process color) and then compact this color/screen information into 16-bit run-length format Transition Data Words. The run length format data words are transferred to the Model 8/32 Processor memory via its DMA channel where they are temporarily held in a scan line data buffer, processed on-line and then transferred to magnetic tape.

The Data Preprocessor operates in three basic modes: Calibrate, Scan, and Test. In the Calibrate Mode "raw" color and lightness measurements are transferred from the Data Preprocessor to the Model 8/32 CPU where color discrimination parameter limits are calculated. As the final step in the Calibrate process, these limits are transferred from the Model 8/32 to the Control Microprocessor and, thence, to the Data Preprocessor where they are stored and used to discriminate colors in the Scan Mode. In the Test Mode, the Control Microprocessor simulates scan data at the Data Preprocessor inputs. The Data Preprocessor formats Transition Data Words and outputs them to the 8/32 Processor where they are printed on the Carousel 30 terminal along with the expected results. A comparison of the actual data with the expected data indicates whether any Data Preprocessor malfunction exists.

10.) (Continued)

For purposes of discussion, the Data Preprocessor can be broken down into four functional sections. These are: Analog Conditioning and Conversion, Color Discrimination and Encode, Transition Data Word Control and, lastly, the Output Logic and Model 8/32 DMA Interface. These functional sections are covered, together with Scan Head inputs, in the description of the operation of the Data Preprocessor in carrying out its major tasks; i.e., conventional color detection and encoding and screen (process color) recognition and encoding. Figure 21 contains a block diagram of the Data Preprocessor showing the functional sections.

Analog Conditioning and Conversion

Within the Scan Head are three spectral color detection channels nominally red, green and blue, which view resolution size areas of the chart and whose photodetector outputs form the basis for resolution element color discrimination. Three screen Scan Head channels, also nominally red, green and blue view larger than resolution size areas. The photodetector outputs from these channels provide a measure of the spectrum over an integrated area of screen reproduction and are used to detect and classify screen color.

The Analog Conditioning and Conversion section of the Data Preprocessor accepts the conditioned analog color output signals from the Scan Head. The signals are summed and ratios of each color channel signal to the total of all channels are formed. The sum of the three channels also provides a measure of lightness, which is the fourth parameter used for color discrimination.

The ratio and lightness color discrimination parameters formed by the Analog Conditioning and Conversion section are summarized below:

SIGNAL	DESCRIPTION
Red Ratio	Ratio of red resolution color detection channel output to sum of red, green and blue resolution color detection channels.
Green Ratio	Ratio of green resolution color detection channel output to sum of red, green, and blue resolution color detection channels.

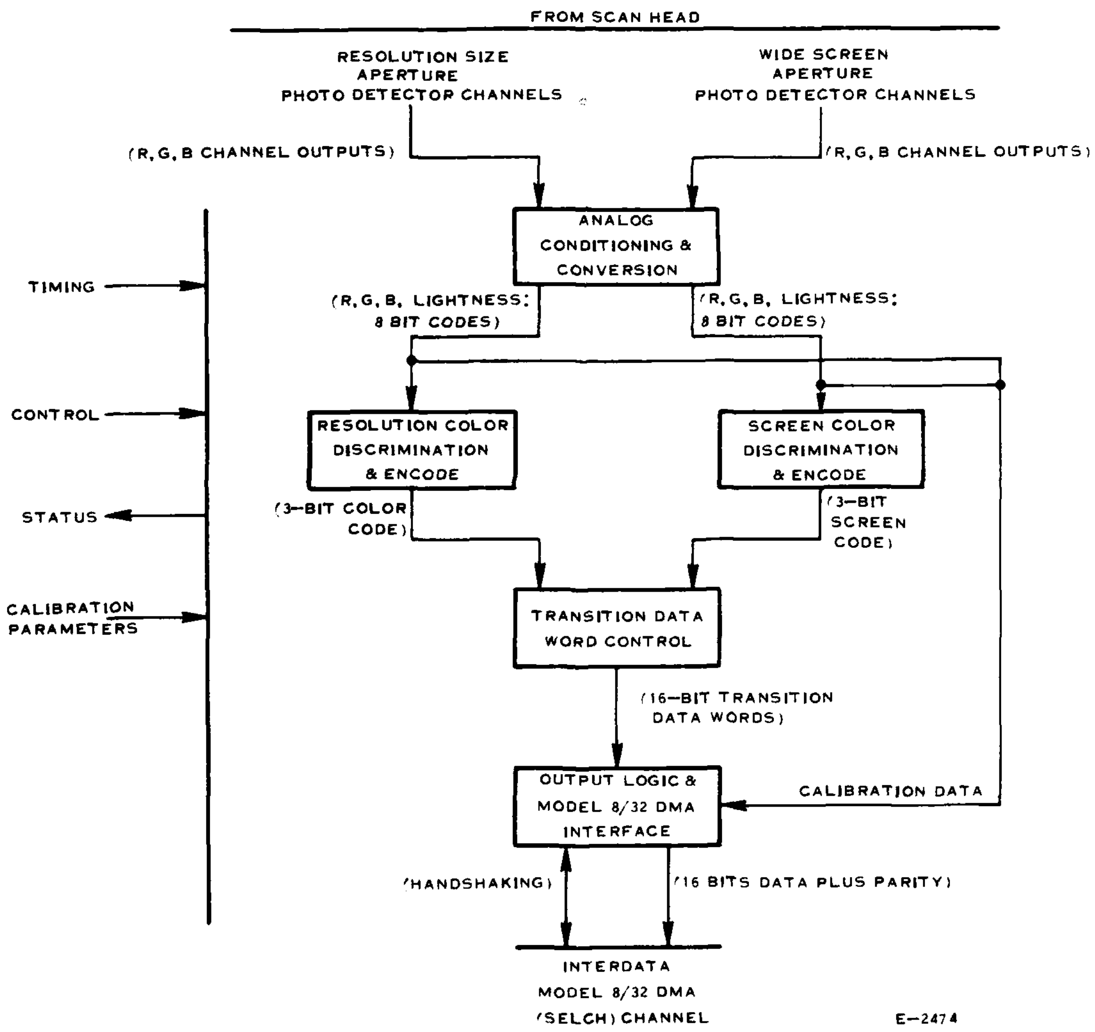


FIGURE 21 DATA PREPROCESSOR FUNCTIONAL BLOCK DIAGRAM

10.) (Continued)

SIGNAL	DESCRIPTION
Blue Ratio	Ratio of blue resolution color detection channel output to sum of red, green and blue resolution color detection channels.
Lightness	Sum of red, green and blue resolution color detection outputs.
SCR Red	Ratio of red screen color detection channel output to sum of red, green, and blue screen detection channel outputs.
SCR Green	Ratio of green screen color detection channel output to sum of red, green, and blue screen detection channel outputs.
SCR Blue	Ratio of blue screen color detection channel output to sum of red, green, and blue screen detection channel outputs.
SCR Lightness	Sum of red, green and blue screen color detection channel outputs.

The resulting signals are sampled at the resolution element rate by the A/D Start Pulse, derived from the X-Position Shaft Encoder XCW output, and converted to 8-bit binary-coded digital quantities. Manual balance controls are employed in the Analog Conditioning and Conversion section to compensate for base material (background) differences between charts.

The outputs of Analog Conditioning and Conversion feed the Color Discrimination and Encode section during the Scan mode and the Output Logic and Model 8/32 DMA Interface during the Calibrate mode.

Color Discrimination and Encode

As part of the calibration process, the Model 8/32 Processor calculates color ratio and lightness high-low limits based upon the data collected from the chart during calibration. The limits are transferred, via the 8/32 multiplexor channel, to the Control Microprocessor. The limits are used by the Control Microprocessor to calculate Color Encode Ram Parameter codes which are loaded into the respective Color Encode

10.) (Continued)

RAMS. Four resolution RAMS (red, green, blue and lightness) and four Screen RAMS are required for the color discrimination process. Figure 18 is an example showing the relationship between the high-low limits and the codes which are loaded into a RAM. Basically, each RAM data bit position corresponds to a color number, and for each color number the data bit is a "one" for the RAM address range falling within the calibration limits for that color, and is "zero" outside the calibration limits.

10.) (Continued)

During the chart scanning process the outputs of the color ratio and lightness A/D converters control their respective Color Encode RAM address lines. At each resolution element along the chart, the code at the output of each RAM has ones at the color number bit positions for which the color under the Scan Head falls within the calibration limits set for that color. The outputs of the four resolution element Color Encode RAMS are input to the (RE) Color Encode Logic. This logic examines the RAM outputs and determines which color number falls within its calibration limits for all four red, green, blue and lightness color discrimination parameters. That, then, is the color which is detected and the 3-bit binary code for the color is output from the Color Encode Logic. If the color under the Scan Head does not satisfy any set of calibration limits, or more than one set of calibration limits is satisfied, the binary code "000" is output indicating the presence of an "uncalibrated color". The (Screen) Color Encode Logic operates in a similar manner; its output being a 3-bit binary number corresponding to the screen color present under the wide aperture screen photodetector, if a calibrated screen is present; otherwise, the output is "000".

The color code outputs of the Color Discrimination and Encode section are input to the Transition Data Word Control. In addition, Mux and Data Routing circuitry provides the means of steering the A/D outputs directly to the Output Logic and Model 8/32 DMA Interface for calibration data collection purposes.

Transition Data Word Control

During calibration, control parameters entered by the operator at the Graphic Display Terminal are transferred to the Transition Data Word Control RAMS by the Control Microprocessor. When scanning, the Transition Data Word Control receives as inputs the sequence of 3-bit resolution color (and screen) codes produced at the output of the Color Discrimination and Encode section and outputs 16-bit run-length format Transition Data Words to the Output Logic and Model 8/32 DMA Interface.

a.) Solid Color Charts

For charts with solid colors only (no screen) the major

10.) (Continued)

a.) (Continued)

functions of the Transition Data Word Control are as follows:

to detect when color transitions have occurred;

to compute a run-length (in terms of resolution elements) for the length of color between color transitions;

to compare each run-length of color against the hardware min span/void filter control parameters stored in RAM and, if a run-length less than the min parameter is detected, attached that run-length to the run-length of the previous color;

to format the 16-bit Transition Data Words which include a 3-bit color code, a 1-bit "type" (solid-screen) code, and an 11-bit color run-length. The sequence of Transition Data Words produced along the scan line provide a complete digital record of the colors detected by the Scanner along that scan line.

Hardware Filtering

The hardware filtering is designed so that invalid color spans and voids are eliminated from the Scanner output data produced in areas of the chart occupied by fill colors without degrading the quality of the encoded line, or symbol, features which appear on the chart. With this capability the amount of data produced by the Scanner is minimized and satisfactory outputs are produced even with charts with marginal printing quality. The basis for this hardware filtering capability are the RE min ΔX length Control parameter and the sixteen RE Min ΔX Length parameters.

Based on a chart examination prior to the scan, the operator classifies via GDT entry each color (number) as an area (fill) color or line (symbol) color. In addition, the operator specifies for each color number two Min ΔX run-lengths:

10.) (Continued)

a.) (Continued)

The first defines the minimum run-length for that color to be valid (i.e., not attached to previous color) when it is immediately preceded along the scan line by a color classified as a line (symbol) color.

The second defines the minimum run-length for that color to be valid with it is immediately preceded along the scan line by a color classified as an area (fill) color.

Figure 22 provides an illustration of typical settings for the hardware minimum span/void control parameters. With the settings shown, run-lengths of two or less of colors 0, 1, 3, 4, and 5 will be attached to the previous color when the previous color is one of the area colors. However, run-lengths of color 2 (normally black) as short as 1 will not be attached to the area colors. In addition, short run-lengths of area colors which follow color 2 will not be attached to color 2.

The parameters which the operator enters at the GDT are converted by the 8/32 Processor to the RE Min ΔX Length Control parameter and the sixteen RE Min ΔX Length parameters and transferred to the Transition Data Word Control RAM via the Control Microprocessor. During the scan these parameters which are stored in the RAM, control the filtering of the area-line color data as it is generated along the scan line.

b.) <u>Screen Charts</u>

The screen areas of charts are calibrated by collecting data from the chart produced by the wide, integrating screen aperture. Using this data the 8/32 Processor calculates screen limits which are transferred to the Control Microprocessor, and loaded into the Data Preprocessor Screen Color Encode RAMS. During the scan it is the function of the Transition Data Word Control to detect when a calibrated screen is present ("000" is uncalibrated screen), and format Transition Data Words with the screen code, type code ("1"), and 11-bit screen run-length. When no screen is present, the Transition

HARDWARE MINIMUM SPAN/VOID CONTROL

COLOR	GROUP L/A (LINE OR AREA)	LINE COLORS — MINIMUM RESOLUTION LENGTH — NEXT COLOR	AREA COLORS — MINIMUM RESOLUTION LENGTH — NEXT COLOR
0	L		3
1	A		3
2	L		1
3	A	1	3
4	A		3
5	A		3
6			
7			

E—2477

FIGURE 22 HARDWARE FILTERING CONTROL (RE COLOR)

10.) (Continued)

b.) (Continued)

Data Word Control must revert to outputting Transition Data Words with a resolution color code based on the resolution aperture color detection. Resolution color and screen Transition Data Words produced along the scan line provide a complete, continuous digital record of the chart along the scan line.

Screen Control

Since the presence of screen is detected with a larger than resolution size screen aperture, it is possible that combinations of solid color line and area features can produce screen photodetector outputs which fall within the range of the calibrated screen(s). The screen control parameters are employed to minimize the possibility of solid color features being lost in the screen aperture area measurement. They also provide the system with a certain amount of immunity to graphic and electronic noise.

SCR Enable/Disable Min ΔX Length Parameters

These parameters are entered at the GDT by the operator and transferred to the Data Preprocessor RAM by the Control Microprocessor. As a rule of thumb, they are set to one-third and one-sixth the width of the screen aperture (in terms of resolution elements), respectively. The function of the "enable" is to assure that the wide aperture is fully over a screen area before screen Transition Data Words are output. The function of the "disable" is to prevent the system from reverting to solid color Transition Data Words if the screen detectors should produce an uncalibrated screen signal for a few resolution elements.

RE Max Color Run-Length Limits and Control

These parameters are also entered at the GDT by the operator and transferred to the Data Preprocessor RAM by the Control Microprocessor. There are eight RE Max Color Run-Length Limits, one for each

10.) (Continued)

b.) (Continued)

color number. Each limit is set so that when a run-length of resolution color is detected, whether a screen color or not, but the run-length exceeds the screen dot (line) width, the Transition Data Word Control reverts to outputting resolution color Transition Data Words regardless of the state of the screen photodetector outputs. The RE Max Color Run-Length Control parameter provides a means of enabling and disabling this function. For example, this function is normally disabled for background (base) color and uncalibrated color.

Figure 23 provides an illustration of typical settings for the Screen Control parameters (1 mm screen aperture assumed). With these settings the wide screen apertures must detect the presence of screen for 13 resolution elements before the Transition Data Word Control begins formatting screen Transition Data Words. Seven resolution elements with no calibrated screen must be present before the Transition Data Word Control reverts to resolution color Transition Data Words. In addition, two resolution elements of colors 2, 4, or 5 will revert the Transition Data Word Control to resolution color Transition Data Words. Color 3 which is assumed to be a screen color (dot width 5) must be present for a run-length of seven before the Transition Data Word Control reverts to outputting resolution color Transition Data Words.

Output Logic and Model 8/32 DMA Interface

The Output Logic and Model 8/32 DMA Inteface consists of a 64 word x 16-bit First In-First Out (FIFO) data buffer and logic required to interface with the Model 8/32 DMA channel. The FIFO buffer temporarily holds the Transition Data Words generated by the Data Preprocessor accommodating the asynchronous timing relationship which exists between the Model 8/32 DMA channel and the Data Preprocessor.

SCREEN (PROCESS COLOR) CONTROL

SCREEN ENABLE LENGTH	13	RESOLUTION ELEMENTS
SCREEN DISABLE LENGTH	7	RESOLUTION ELEMENTS

(SCREEN DISABLE) MAX (RES) COLOR RUN LENGTH

COLOR	FUNCTION ENABLE/DISABLE	MAX COLOR RUN LENGTH – RESOLUTION ELEMENTS
0	D	–
1	D	–
2	E	2
3	E	7
4	E	2
5	E	2
6		
7		

E–2478

FIGURE 23 SCREEN CONTROL PARAMETERS

11.) Test Panel

The Test Panel i located in the Processing Console, accessible behind the front door. The panel provides the following functions:

Test Jacks for monitoring of all low voltage supplies in the Processing Console and Scanner Unit (Equipment Bay).

Voltage Adjust pots for all low voltage supplies in the Processing Console.

Preprocessor BITE ENABLE switch and A/D BITE display for A/D outputs.

Test jacks for selected points in the Preprocessor analog signal n-th.

X encoder inde, ,ulse (Xo) for oscilloscope synchronization.

8080 RESET pushbutton.

8080 TEST (BENO) switch for miscellaneous software features.

Stepper motor HALF STEP indicator.

All jacks on the Test Panel are for use with a voltmeter or oscilloscope. The PMT and Ratio jacks are used for troubleshooting and calibration of the analog signal path. The Equipment Bay jacks allow monitoring of the Scanner Unit power supplies. The Processing Console power adjust section allows monitoring and calibration of the low voltage supplies in the Processing Console. Xo is a logic pulse produced by the X encoder every drum revolution. The 8080 TEST (BENO) switch is sensed by the 8080 for use in various features of the microprocessor software. The BITE ENABLE switch controls the power to the A/D BITE display, supplies +28 to all the BITE relays in the Preprocessor and grounds the center pole of the BITE SELECT rotary switch. The BITE SELECT grounds one of 8 A/D Bite Test enable lines, which, at the Preprocessor, places an A/D output on lines TST8 - TST1. The A/D output selected is thus displayed in octal format on the A/D BITE display.

12.) 8080 Software Diagnostic Procedures

Off-line and on-line diagnostics are stored in PROM memory. The off-line diagnostics disable the normal scanning control sequence and are used only when the scanning operation is stopped. On-line diagnostics are run with the scan in process.

Off-Line Diagnostics

These diagnostics are stored in PROM memory. They are used to isolate malfunctions and test the sections of circuitry the microprocessor has access to. With the diagnostic running, the operator communicates directly with the microprocessor via a CRT and keyboard commanding any series of tests desired. During this time, the normal operation of the Scanner is suspended.

To run the diagnostic, a RS-232, 4800 baud CRT terminal must be connected to the microprocessor. A special adaptor is provided for this purpose. The adapter plugs onto the printed circuit connector of the rightmost card in the lower cardrack in the Processing Console. The Terminal's connector plugs into this adaptor. Any RS-232, 4800 baud terminal may be used including the Textronix 4006-1 supplied as part of the Scanner system.

To start the diagnostic, the Processing Console Test Panel switch labelled 8080 TEST (BENO) is placed in the up position and the Test Panel 8080 RESET switch is depressed. The diagnostic will then start performing a memory check to verify the integrity of the PROM memory. If this test passes, "HI-HO HELLO" is placed on the X and Y Address displays and the CRT signs on and prompts for a command. If the self-check fails, HELP 6 appears on the displays.

There are seven diagnostic tests that may be run. These are described in the paragraphs which follow.

a.) Light Test

This test is used to diagnose problems associated with the control panel indicators.

After the command summary has been printed, the CRT prompts with a " - ". In response, "A" is typed to

12.) (Continued)

a.) (Continued)

call up the Light Test. This enters the light test. Following the printed instructions, the space bar is depressed and the specified indicator is checked to be on or off. When the test is completed, a "Y" or "N" is entered to indicate whether the test is to be run again. If "N" is entered, the command summary is printed and the CRT prompts for a new command.

b.) Analog Front End Test

This test is used to check the analog circuitry up to and including the A/D converters. The test is entered by entering a "B" at the keyboard.

The CRT responds to "B" by printing a list of subtests and prompting with a "*". At this point in the test, the A/D BITE circuitry is enabled and the BITE display may be used. If an "A" is typed, the outputs of all eight A/D converters are printed in hexadecimal and percentage of full scale.

If a "C" is typed, an estimation of the color seen by the screen and resolution element channels is made on the basis of preset limits in the Data Preprocessor Color Encoder.

To exit the test, "E" is typed. The CRT responds by printing the command summary and prompting for a new test.

c.) Display Test

This test is used to check the X and Y Address displays. The test is entered by typing a "C". The program then prompts for entries that blank or unblank the displays and enter any combination of displayable characters on the displays.

d.) Switch Test

This test checks the control panel switches. The test is entered by typing "D". Once the test is entered, depression of a control panel pushbutton will cause the name of that switch to be displayed on the CRT.

12.) (Continued)

d.) (Continued)

The switches may be depressed in any order. If a switch depression results in an invalid code, the code is displayed in hexadecimal. Depression of the Scan Head Control Panel READ STAT COLOR, READ DYN COLOR or READ CONT POINT switches causes the NUMBER Thumbwheel switch code to be displayed. The Main Control Panel STOP pushbutton terminates the test.

e.) Preprocessor (Transition Data Word) Test

This test is entered by typing "E". This runs the Preprocessor test, which has a set of commands of its own and provides a means of tracking down suspected Preprocessor faults. The functions callable by this routine are:

Transfer calibration parameters. This subtest ships the A/D contents to the 8/32 as the 4 listed 16-bit words.

Change Transition Data Word parameters. Subtest allows change of any parameter in the TDW section of the Preprocessor.

Begin Scan. Clears all necessary hardware and sets up to begin sending data.

Repeat Previous Scan. Repeats previous color string entered during last simulated scan. On startup, there is a representative scan line in place of any previous scan data.

Status of System. Anytime during the test, this routine may be used to read all sections of the TDW and FIFO accessible to the 8080 system.

End Scan. Ends the scan line as if a normal scan was in progress.

Output color string. Simulates the reception of a resolution or Screen color of any length at the color encode section. This allows modification of the "canned" scan line or generation of a new scan line.

f.) Encoder Test

This test checks the X and Y Position Shaft Encoder circuitry. By typing "F", a continuous display of the X and Y position counters is generated. Manual positioning of the drum and scan head may then be used to verify proper functioning of the circuitry.

g.) Ballscrew Test

This test is entered by typing "G" and depressing the Main Control Panel START PROCESSING pushbutton. The test performs a check of Y position over the useful length of the ballscrew by comparing motor position with Y encoder position. The detailed test sequence follows:

1.) Start at position 000000.

2.) Accel-slew-decel to motor position 000400.

3.) Compare motor and encoder derived positions.

4.) Step back four .025 mm steps; motor backphasing follows each step.

5.) Compare motor and encoder derived positions.

6.) Step forward four .025 mm steps; motor backphasing follows each step.

7.) Compare motor and encoder derived positions.

8.) Repeat steps 2 - 7 at motor positions 000800, 001200, 001600 up to and including 100000.

9.) Repeat steps 2 - 7 starting at motor position 100000 and moving to 000000 in 400 step increments.

10.) Repeat steps 1 - 9 starting a motor position 000080 and advancing by 400 for all subsequent positions. (000480, 000880, etc.)

11.) Repeat steps 1 - 9 starting at motor position 000160 and advancing by 400 for all subsequent positions. (000560, 000960, etc.)

12.) (Continued)

g.) (Continued)

12.) Repeat steps 1 - 9 starting a motor position 000240 and advancing by 400 for all subsequent positions. (000640, 001040, etc.)

13.) Repeat steps 1 - 9 starting at motor position 000320 and advancing by 400 for all subsequent positions (000720, 001120, etc.)

When the test is running the Main Control Panel X Address displays the "offset" (0, 80 , 160, etc.) and the Y Address displays the current position. If a failure occurs, the test stops. The Y Address displays the motor position and the X Address displays the Y encoder position. Additional diagnostic messages are displayed on the CRT.

This test is run by default if the adaptor plug is left unconnected to the 80/20 card in the microprocessor chassis and the START PROCESSING pushbutton is depressed.

h.) Monitor

A general purpose monitor is available which allows the user to examine and modify any 8080 accessible memory location or port. This allows manipulation of any I/O interface or examination of PROM or RAM, including Preprocessor control parameters.

To enter the monitor, type "I". This displays the commands available. There are five operations which may be performed. They are listed as follows:

Examine Memory Location - This allows examination of any memory (PROM or RAM) location accessible to the 8080.

Press "A". This causes the 8080 to ask for an address. Enter the address in decimal or hexadecimal (hexadecimal must be followed by an "H"), then press "RETURN". Memory location will be displayed.

12.) (Continued)

h.) (Continued)

Change Memory Data - This allows test and change of RAM locations.

Press "D". This prints the last memory location examined and asks for new data. Enter the new data, followed by "RETURN".

Jump to Memory Location - This allows a direct jump to any point in memory to execute instructions stored in PROM or RAM.

Press "J". This causes the 8080 to ask for an address to jump to. Enter the address and the 8080 begins executing code at that point in memory.

Repeat Examine or Change operation on Next Location - This allows strings of Examines or Changes to be made without having to enter new addresses.

Press "N". This prints the address and contents of the memory address one greater than the last address examined or changed. New data is prompted if the last operation was a change.

Port Input-Output - This allows any input port to be read and data to be sent to any output port.

Press "P". This causes the 8080 to prompt for a port address. Enter the address (decimal or hex). The input port specified is displayed and the 8080 prompts for output data. The data entered (decimal or hex) is output to the specified port.

Troubleshooting with the Diagnostic

Usage of the diagnostic is helpful in the location of problems in the 8080 controlled hardware and interfaces. The tests provided allow direct testing of the more complicated functions. The monitor allows the testing of individual functions of the 8080 interfaces. All possible tests for every part of the system cannot be covered, but the following two examples indicate how the monitor may be used to locate problems that otherwise would be very difficult to locate:

12.) (Continued)

Example 1

Assume a PROM failure occurs. The most common cause of this is a failure of one of the 17 PROM integrated circuits in the system. On power-up, this results in a "HELP" message appearing on the X and Y Address displays. The problem is to locate which of the 17 PROMS is faulty.

Unless the failure is in the first PROM, the 8080 will jump directly into the diagnostic when a PROM failure occurs. Thus, the monitor may be used to execute code which will test individual PROMS. Examine the diagnostic program source listing. At address 7FC7H is a short code segment which may be run to test any single PROM. By jumping to this location, the 8080 can be used to do a CRC check on any single PROM. The 8080 asks for the PROM start address. When this is typed in, the CRC sum is generated and printed. The value returned indicates if the PROM is faulty and must be replaced.

Example 2

Assume the light control interface fails. The Light Test indicates that the lights controlled by port "CC" do not respond. Assume the board has been placed on the extender card and an oscilloscope is being used to check the signals used to control the light interface. In order to examine these signals during a port write operation, the 8080 must be forced to repeatedly output a data byte to the light interface output port at address "CC" (hex). To do this, we must store a short program in RAM which outputs data to the port and loops continuously while we examine the signal lines. The simplest program would be the following:

Address	Data	Instruction	Comments
3B00H	3EH	MVI A,62A	;LOAD A register with
3B01H	62H		;the word which
			;turns on the RESET
			;Y light.
3B02H	D3H	OUT CCH	;OUTPUT the contents
3B03H	CCH		;of A to Output
			;port "CC".

12.) (Continued)

Example 2 (Continued)

Address	Data	Instruction	Comments
3B04H	C3H	JMP 3B00H	;Jump to address
	00H		;3B00H and repeat
	3BH		;program

The data sequence representing the program is loaded into RAM using the monitor. Then, by jumping to address 3B00H, the 8080 is forced to execute the program loop continuously, allowing the troubleshooting of the light interface.

12.) (Continued)

On-Line Diagnostic

The 8080 TEST (BENO) switch is used in conjunction with the Scan Head Control Panel NUMBER switch to activate on-line diagnostic test routines which--

set up special Scanner operating modes.

provide a readout of the frequency of occurrence or time interval between critical events in the scanning control sequence.

provide a readout of certain status parameters.

To enter these special routines the 8080 TEST (BENO) switch on the Processing Console Test Panel is flipped up and the NUMBER switch is set for the test routine required. Setting the NUMBER switch to "00" initializes all tests, counts, flags, etc.

A summary of the function provided by each NUMBER switch setting follows:

NUMBER = 00 - Resets all flags and counters.

NUMBER = 02 through 85 - The X-ADDRESS readout displays the Y-Position Shaft Encoder derived position at the 0.0125 mm resolution.

NUMBER = 50 - Sets resolution to 0.025 mm.

NUMBER = 51 - Sets resolution to 0.05 mm.

NUMBER = 52 - Sets resolution to 0.1 mm.

NUMBER = 77 - The X-ADDRESS readout displays the Y-Position Shaft Encoder derived position at the 0.0125 mm resolution. The Y-ADDRESS readout displays the stepper motor count position at the 0.0125 mm resolution. The STEP (RIGHT, LEFT) switch advances the Scan Head one 0.0125 mm step for each depression of the switch.

NUMBER = 87 - The X-ADDRESS readout displays the number of 8080 to 8/32 transmission retries.

AD-A080 469 UNITED TECHNOLOGIES CORP WINDSOR LOCKS CONN HAMILTON --ETC F/G 8/2
A COLOR RASTER SCANNING SYSTEM FOR DIGITIZING CARTOGRAPHIC DATA--ETC(U)
NOV 79 D MODEEN, S NIEMCZYK, F SUNDERMEYER F30602-76-C-0205
UNCLASSIFIED HSER-7673 RADC-TR-79-286 NL

2 OF 2
AD
A080469

END
DATE
FILMED
3-80
DDC

12.) (Continued)

On-Line Diagnostic (Continued)

NUMBER = 88 - The X-ADDRESS readout displays the Scan Speed Status. (0 = Scan Speed)

NUMBER = 89 - The X-ADDRESS readout displays the status of the 5 MSEC Timer. (255 = bad timer)

NUMBER = 90 - The X-ADDRESS readout displays the number of Data Preprocessor FIFO overflows which have occurred.

NUMBER = 91 - The X-ADDRESS readout displays the number of times the stepper motor pulse sequence was not completed before the next Xo′ occurred.

NUMBER = 92 - The X-ADDRESS readout displays the time in MSEC from Xo′ to the time the 8080 sends the first pulse to the stepper motor.

NUMBER = 93 - The X-ADDRESS readout displays the time duration from Xo′ to Xo′ (± 5 MSEC).

NUMBER = 94 - The X-ADDRESS readout displays the number of 8/32 Scanning Control Block retries which have occurred.

NUMBER = 95 - The X-ADDRESS readout displays the number of 8/32 to 8080 Scanning Control Block Transmissions which have occurred.

NUMBER = 96 - The X-ADDRESS readout displays the number of End Scan + 1 MSEC Interrupts which have occurred.

NUMBER = 97 - The X-ADDRESS readout displays the number of Start Scan Interrupts which have occurred.

NUMBER = 98 - The X-ADDRESS readout displays the number of Xo′ Interrupts which have occurred.

NUMBER = 99 - The X-ADDRESS readout displays Y-Position Shaft Encoder derived Scan Head position at the resolution selected.

SECTION VI

SOFTWARE DESCRIPTION

A.) Analysis of Functional Requirements

Requirements in designing the software for the Color Raster Scanner to comply with the Statement of Work dictated consideration of operator interface. The Graphics Display Terminal (GDT) is used as the primary operator interface for the Color Raster Scanner software. It displays a series of "menus" which direct the operator's actions and prompts parameter entries. The Carousel 80 Keyboard/ Printer is employed as a main system console, to activate and terminate the Color Raster Scanner software. It is also used as a hardcopy device for listing operational parameters and as an error message log and error recovery device.

The Scanner Unit and Main Control Unit of the Color Raster Scanner are under control of an 8080 microprocessor. To allow interaction between the 8080 microprocessor and the main 8/32 computer, a communication protocol was required. The protocol was designed in terms of command/control transmission blocks which are sent in both directions between the 8080 and 8/32.

Scanning of a chart requires real-time data to be acquired from the Scanner Unit as the drum is rotating. To accomplish the data acquisition, a Direct Memory Access (DMA) interface is used between the Scanner Unit and 8/32 computer.

A Real-Time Display of the data being collected as the Scan is proceeding is required by the Statement of Work, and is used to allow the operator to determine if the On-Line Scan is proceeding satisfactorily. The GDT is used as the display device. The Real-Time Display was designed to allow the section of the chart which is to be displayed, be selected prior to initiating the scan and also be changed during the scan cycle.

Calibration of the color set for every chart to be scanned by the Color Raster Scanner is required. To accomplish the calibration, areas containing only one color are identified on the chart. These areas are scanned and the data from these areas examined to determine limits for each color. These limits are modified by the operator through an interactive procedure to obtain the best calibration.

A.) (Continued)

Data collected from the scan normally does not adequately reproduce the graphic representation of the chart. Editing is required to correct the anomolies which appear in the data. The editing is performed during a post-processing phase on the scanned data. The operator selectable editing functions designed to correct anomolies in the data and meet certain Statement of Work requirements include:

Min Span - Min Void - Uncal Color -

fills in small voids and deletes small flecks of colors.

Overprint -

prevents background from appearing due to misregistration in the chart reproduction between adjacent colors.

Min Area Removal -

removes uncalibrated color areas adjacent to boundaries and miscalled color areas, and replaces them with neighboring colors.

Screen Boundary Correction -

corrects a narrow strip near the boundary of screen colors which has not been correctly identified as screen color.

Color Delete -

changes any selected color to the background color.

Support functions are also included in the post-processing phase to additionally correct chart data anomolies and provide utility functions required by the Statement of Work. These functions include:

Chart Thickness Correction -

corrects errors in distances caused by the chart thickness.

Area Delete -

converts operator specified areas into the background color.

A.) (Continued)

Distortion Removal -

corrects lineal distortion in the X and Y directions.

Produce Color Separation Tape -

produces single color tapes in the format required for the Raster Finishing Plotter.

Change of Scale -

expands or contracts the size of the chart by an amount specifies by the operator.

Chartlet Merge -

provides the capability to combine two scanned data files in order to update a scanned raster file by the introduction of an amendment.

Skew Removal -

provides the capability to rotate the data of a scanned chart.

B.) Software Organization

Menu Structure

Operator interface to the 8/32 computer is based primarily on menus presented via the Tektronics Graphic Display Terminal (GDT). The structure of the menus is based on a hierarchical arrangement. Using control commands, the operator can vector to any desired menu, or follow a preprogrammed sequence through the menus.

Each menu contains instructions to the operator and/or requires entries from the operator. Data entry is on a line-by-line basis. As each menu is displayed, the operator may optionally modify entries appearing on the screen. To assist in updating and sequencing through the menus, control commands are available to the operator.

The Master Mode Menu is the menu which appears on the GDT when the System is first started. This menu allows the operator to select any of the major modes of operation. When one of the major modes

B.) (Continued)

Menu Structure (Continued)

is selected, the first menu in the selected mode will appear on the screen. The operator may then select a particular subset function, as in the Calibration or Post-Processing Mode, or use a preprogrammed sequence to sequence through the menus and perform the necessary entries.

Calibration

Color calibration is an operator interactive procedure to determine limits for the Color Raster Scanner to allow the correct color identification of data input from a chart. The Color Raster Scanner inputs data for calibration from three spectral channels (red, green and blue), and a lightness channel (the summation of the three spectral channels). Limits for all four channels must be determined for every color appearing on the chart which is to be identified.

The calibration procedure begins when the operator identifies small areas and points on the chart which contain only one color. These areas are then scanned and values representing the percent reflectivity in all four channels stored on disc for a sampling of elements in the areas.

The calibration limits for each color are initially set to the minimum and maximum values detected in each of the four channels. The operator modifies these limits based on an interactive procedure. Information displayed on the GDT indicates where and how much conflict exists in the limits. The operator modifies the limits and observes the results of the modification. If the results are not satisfactory, the limits are modified again.

Scan

The Scan software is used to control and coordinate scanning during the on-line data storage to mag tape. This real time software controls the decisions to advance the Scan Head, read the DMA data input channel, and display and output the collected data. The Scan software also performs an on-line chart thickness correction, provides a real-time display, detects errors and handles error recovery.

At the end of every drum revolution during the scan, the Scan software communicates to the 8080 microprocessor. Based on any

B.) (Continued)

Scan (Continued)

error indicators received from the 8080 or other sources, a decision is made to advance the Scan Head, rescan a partial or full line, or abort the scan. The decision is communicated to the 8080 as well as acted upon by the Scan software. If the decision is to advance the Scan Head, the data read in from the current line is processed. The processing involves performing a chart thickness correction, attaching a line number, and passing the data on to be output and displayed on the GDT.

Post-Processing

Post-Processing provides the capability to process scan record tapes to produce either edited scan record tapes, or color separation tapes. Some of the functions are incompatable, and must be performed in separate stages. Both the skew removal and chartlet merge functions must be run alone. They automatically produce scan record tape output. The other functions can be selected in any combination, with the exception that scan record tapes and color separation tapes cannot be produced at the same time.

8080 - 8/32 Communication

The 8080-8/32 communication protocol is defined in terms of command/control transmission blocks which are sent in both directions between the 8080 and 8/32. Communication between the two machines is initiated at either the 8080 (Control Panels) or 8/32 (GDT) end depending on the transmission type. Each transmission by one machine is acknowledged by the other using a communication protocol which is half duplex. Each command/control transfer sent is acknowledged explicitly by a TRANSMISSION ACKNOWLEDGED, or an 8080 STATUS TRANSMISSION, or by the LAST ID code which is part of the next transmission sent. A (LRC) CHECKSUM included in each transmission is used to check data integrity. The CHECK SUM is calculated by summing all bytes in the transmission discarding overflows. An incorrect LAST ID or a faulty CHECK SUM causes error messages to be displayed and the Scanner operation to be halted. If a CHECK SUM error is detected, transmission retries will be executed before the Scanner is halted and a fault message is displayed.

Each command/control block consists of 5 16-bit words having the following format:

B.) (Continued)

8080 - 8/32 (Continued)

	BIT 15 — BIT 5	BIT 4 — BIT 0
WORD 1	← STATUS BITS →	CONTROL/COMMAND ID

	BIT 15 — BIT 0
WORD 2	X OR Y ADDRESS

	BIT 15 — BIT 0
WORD 3	X OR Y ADDRESS

	BIT 15 — BIT 8	BIT 7 — BIT 0
WORD 4	FAILED RAM POSITIONS	LAST ID

	BIT 15 — BIT 8	BIT 7 — BIT 0
WORD 5	CHECKSUM	CONTROL POINT OR COLOR NUMBER

Specific fields in the control/command block are unused depending on the control/command ID.

The following summarizes the communication sequences for each transaction in the 8080 - 8/32 protocol:

Read Control Point

8080		8/32
READ CONTROL POINT COMMAND	⟶	
	⟵	TRANSMISSION ACKNOWLEDGED

B.) (Continued)

Read Dynamic Calibration Coordinates

8080		8/32
READ DYNAMIC CALIBRATION COORDINATES COMMAND	→	
	←	TRANSMISSION ACKNOWLEDGED

Read Static Color

8080		8/32
READ STATIC COLOR COMMAND	→	
	←	TRANSMISSION ACKNOWLEDGED
	←	TRANSFER DATA TYPE COMMAND
(CAL DATA TRANSFER, DMA)	→	
8080 STATUS TRANSMISSION	→	

Resolution/Mode Command

8080		8/32
	←	RESOLUTION/MODE COMMAND
8080 STATUS TRANSMISSION	→	

Receive Calibration Parameters

8080		8/32
	←	RECEIVE CALIBRATION PARAMETERS COMMAND
8080 STATUS TRANSMISSION	→	

Test Transmission

8080		8/32
	←	8/32 TEST TRANSMISSION
8080 TEST TRANSMISSION	→	

B.) (Continued)

Scan

Protocol Summary

8080	8/32

START PROCESSING COMMAND →

← TRANSMISSION ACKNOWLEDGED

← Y-RECOVER COMMAND

8080 STATUS TRANSMISSION →

Y-RECOVER ACKNOWLEDGED →

← TRANSMISSION ACKNOWLEDGED

← TRANSFER DATA TYPE COMMAND

8080 STATUS TRANSMISSION →

8080 SCANNING CONTROL BLOCK →

← 8/32 SCANNING CONTROL BLOCK

8080 SCANNING CONTROL BLOCK →

← 8/32 SCANNING CONTROL BLOCK

ETC..... until terminated by END OF CHART, STOP PROCESSING or error condition.

Editing

The editing techniques used in the Color Raster Scanner were designed to improve the quality of the scanned graphic and to meet specific requirements defined in the Statement of Work. The two editing techniques which provide the most improvement in graphic quality are the Min Span-Min Void-Uncal Color routine and the Min Area routine.

The Min Span-Min Void-Uncal Color routine is an adaption of a similar technique used on a previous Color Scanner developed by Hamilton Standard. In the original technique one minimum span

B.) (Continued)

Editing (Continued)

length for all colors was established and a minimum void length was established. If a color was found with a run length less than the minimum span length it was deleted, if a void was found with a run length less than the minimum void length the length was added to the preceding color.

The new technique allows a different minimum length to be established for every color. When a run length of a particular color is found to be less than its minimum length, it is deleted and filled in by the surrounding color. Figure 24 demonstrates the difference in techniques. The new technique allows larger settings of minimum color length without fear of "generating" color where it does not appear in the original graphic.

The Min Area routine is an adaptation of a technique described in a paper "A New Image Enhancement Algorithm with Applications to Forestry Stand Mapping."* The original technique dealt only with black and white images and was modified and expanded to process multicolor scanned graphics.

The Min Area technique locates and identifies area in the scanned graphic which are of the same color. Each color in the scanned graphic has an operator entered minimum area size. If an identified area of color is smaller than the minimum area size, it is deleted and filled in by the surrounding color.

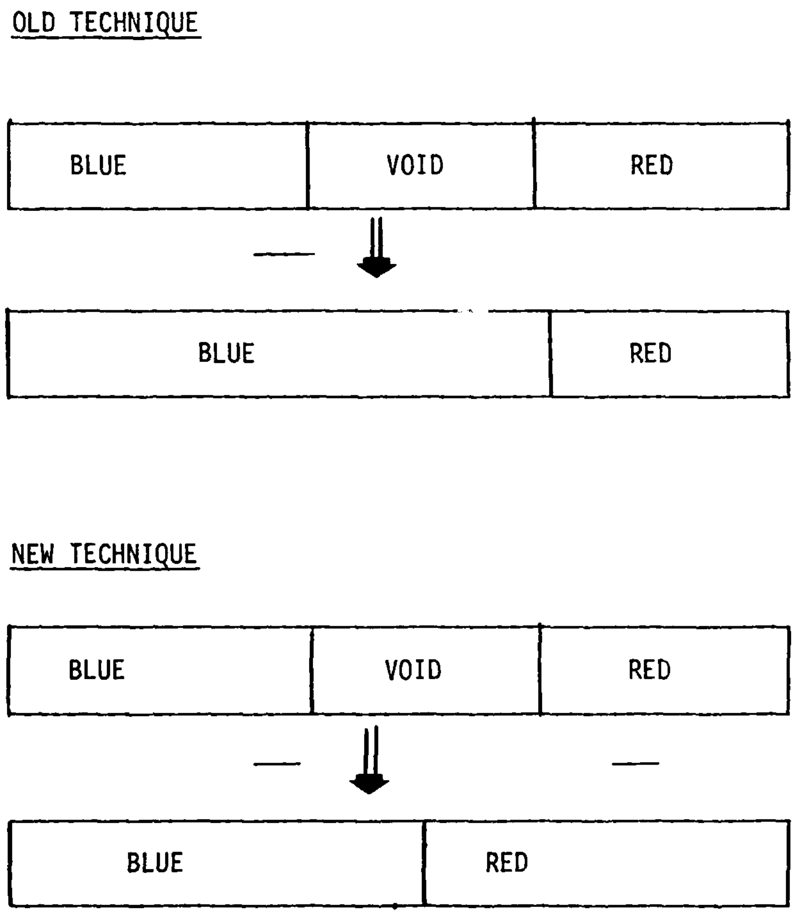
The Screen Boundary Correction routine is another important editing technique. A special optical configuration is used to encode screen or process color as a single solid color, rather than as the individual colors it is composed of. This encoding technique leaves a border around the encoded screen color. The border is not identified correctly as screen color, but of the component colors. The Screen Boundary Correction routine corrects this problem by extending the screen color into the border area.

The Color Delete routine was incorporated to meet the Statement of Word requirement Paragraph 4.1.4.6. Any operator selected color is changed to the background color by this editing technique.

Support Functions

The Support Functions were designed to meet various Statement of Work requirements. The Chart Thickness Correction routine was

*Lockheed Electronics Company, Inc.,National Aeronautics and Space Administration-Lyndon B. Johnson Space Center- Houston, Texas- June 1975.



MIN SPAN - MIN VOID CORRECTION

FIGURE 24

B.) (Continued)

Support Functions (Continued)

designed to compensate for chart thickness in the range of 0 to 1 millimeter during the on-line scan.

The Area Delete routine was designed to meet the Statement of Work requirements for the capability of deletion of areas selected by the operator. Areas are identified as rectangles by identifying the four corners while the chart is mounted on the drum. During the post-processing phase of the Color Raster Scanner, the identified area is converted to the background color.

The Distortion Removal routine was designed to meet the Statement of Work for the correction of distortion of the chart base. Four points of known latitude and longitude are identified on the chart. Using the chart scale and projection, the desired distances between the points is computed. During the post-processing phase of the Color Raster Scanner, linear correction factors are applied to the chart to fit the chart as closely as possible to the desired dimensions.

The Change of Scale routine was designed to meet the Statement of Work for change of scale of the data read from the chart. It allows the dimensions of the chart to be multiplied by a scale factor between 0.25 and 4.00.

The Chartlet Merge routine was designed to meet the Statement of Work for the update of a source chart. Amendments to a chart are mounted on the chart in their correct location. The amendments are scanned separately from the chart. During the post-processing phase of the Color Raster Scanner, the scanned amendment is merged into the data file containing the originally scanned chart. The merge produces a data file containing the scanned chart with the amendments.

The Skew Removal routine is not a requirement of the Statement of Work but is a subset of the Chartlet Merge function. Access to this routine was provided to allow a maximum of 200 lines of skew to be removed from a scanned chart.

Test and Evaluation

Initial testing of the software uncovered no problems in the design of the software. Normal, anticipated problems such as software coding errors, and interfacing problems with the hardware, were

B.) (Continued)

Test and Evaluation (Continued)

encountered and corrected.

Further testing revealed a paper scattering effect which caused problems near line edges. As the encoding aperture approached a line edge, the signal level received changed gradually. A rapid change in the signal level would normally be expected as the encoding aperture crossed the line edge. Figure 25 depicts the signal level change. The scanned graphic resulted in an encoded line, bounded by a region of uncalibrated color. Normally the encoded line width was not correct.

Initially, it was attempted to solve the problem by obtaining calibration samples near the edges of the colors. This procedure usually resulted in a smaller region of uncalibrated color bounding the line color, but the line width was not controllable. Also, when other colors were present on the chart, the calibration procedure of setting limits became more difficult if samples were obtained near the line edges.

It was eventually discovered that the line weight could be controlled by directly modifying the lightness channel limits of the line color. The software was modified to allow the operator to display and modify the lightness channels of all colors.

Another problem discovered occurred in the results of the post-processing editing phase. A region of uncalibrated color still bounded the line colors even though the line width could be controlled during calibration. The editing would attempt to correct the uncalibrated color region. Because of the method the editing technique used, the line color would be extended halfway into the uncalibrated region. The editing thereby destroyed the effects of being able to control the line width during calibration.

Another problem with the line colors occurred during the screen boundary editing. Normally on a chart the screen colors were bounded by a line color. The screen boundary editing would extend the encoded screen color and correctly fill the region to the boundary around the encoded screen color. Under certain circumstances, the screen would be extended further then necessary and also overlay the line color surrounding the screen color.

These problems with the line colors were overcome by the intro-

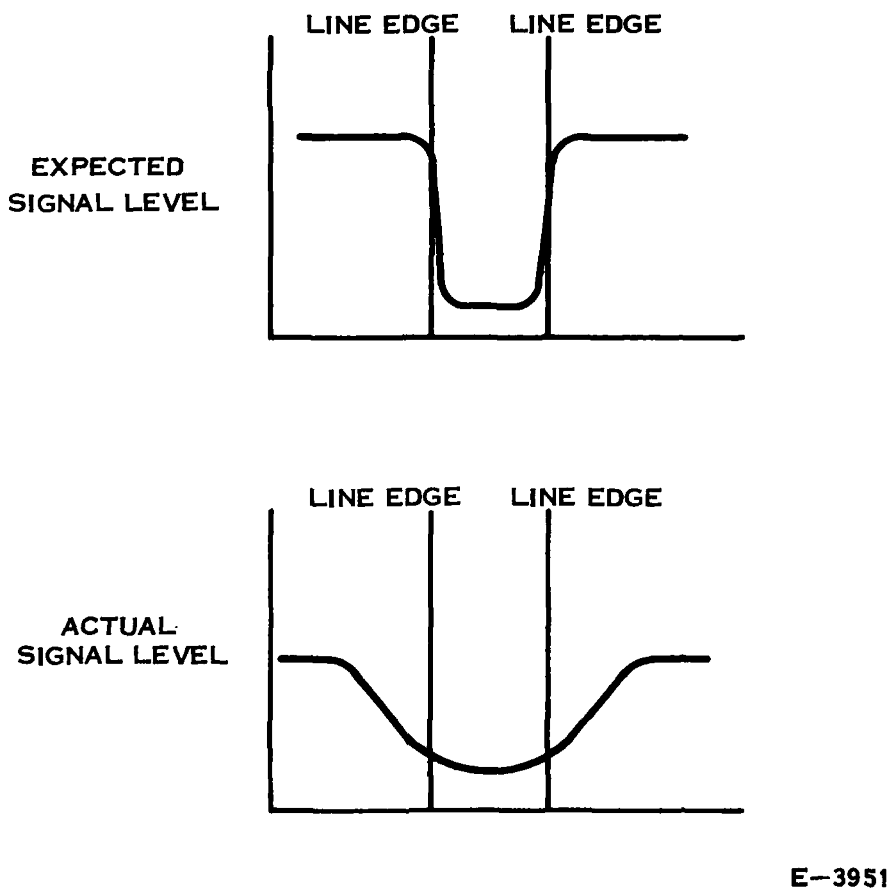


FIGURE 25 PAPER SCATTERING EFFECT ON SIGNAL OBTAINED CROSSING LINE EDGE

B.) (Continued)

Test and Evaluation (Continued)

duction of the concept of "protected" colors. The operator could identify which colors on the chart were "protected". During the post-processing editing phase, the colors identified as "protected" would not be modified by the editing. This concept was slightly modified for the Min Span-Min Void-Uncal Color editing routine. If a color having a run length less than the minimum run length for that color was bounded on both sides by a protected color, the color would be deleted and filled in by the protected color. This modification allowed small voids within a protected color to be edited, whereas strict adherence to the "protected" color rule would not have allowed a modification to the protected color.

Other editing functions not provided in the final edited chart, could enhance the final product before going to an interactive editing process. One involves a complication encountered because of the "protected" color concept. When the Min Area editing routine encounters an area of color less than the minimum area for that color, it attempts to fill in the area on a line-by-line basis. If the area is bounded by a "protected" color, the area will not be filled in. Figure 26 illustrates this problem. Modification of the area fill algorithm in the Min Area routine to use more sophisticated techniques to determine the fill color may help in this situation.

Another result of the "protected" color concept occurs when there is a large boundary of uncalibrated color bounding the line colors. Normally, setting a high value for the minimum run length of uncalibrated color for the Min Span-Min Void-Uncal Color routine would edit out the uncalibrated color. Because the Min Span-Min Void-Uncal Color editing routine was modified to allow it to fill areas bounded by protected colors, a tendency to fill in characters appearing in the scanned chart results if the minimum run length is set too high. Figure 27 illustrates this problem. Modifying the Min Span-Min Void-Min-Uncal Color editing routine to allow two minimum run length limits, one when the run length is bounded by "protected" colors and one when not, would solve this problem.

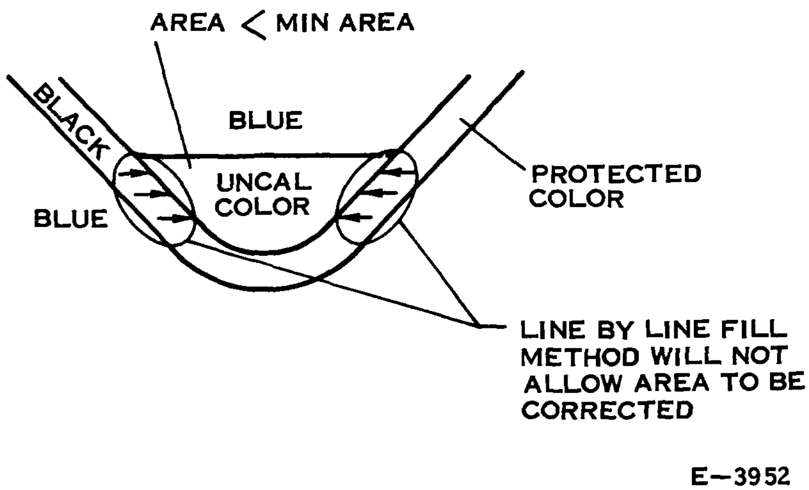
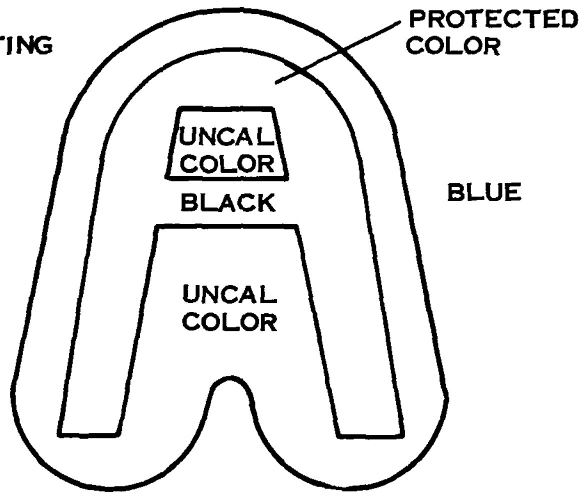
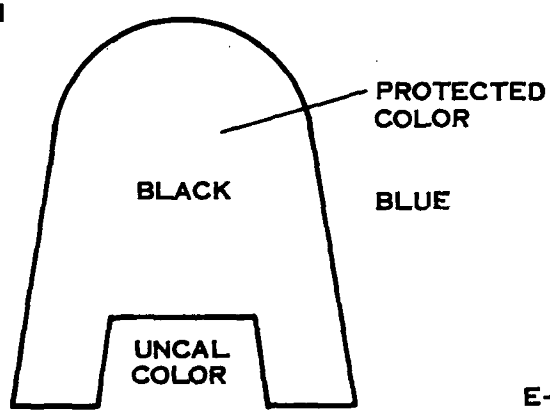


FIGURE 26 EFFECT OF PROTECTED COLOR ON MIN AREA FILL TECHNIQUE

BEFORE EDITING



AFTER
EDITING BY MIN SPAN—MIN VOID—UNCAL COLOR
WITH MIN RUN LENGTH FOR UNCALIBRATED
COLOR SET HIGH



E—3953

FIGURE 27 EXAMPLE OF EDITING PARAMETER SETTING ENHANCING DATA, BUT ALSO CAUSING LOSS OF DATA

MISSION
of
Rome Air Development Center

RADC plans and executes research, development, test and selected acquisition programs in support of Command, Control Communications and Intelligence (C^3I) activities. Technical and engineering support within areas of technical competence is provided to ESD Program Offices (POs) and other ESD elements. The principal technical mission areas are communications, electromagnetic guidance and control, surveillance of ground and aerospace objects, intelligence data collection and handling, information system technology, ionospheric propagation, solid state sciences, microwave physics and electronic reliability, maintainability and compatibility.